INSTRUCTION MANUAL
FOR
MODEL 4220-S/3
N00104-89-D-0052
7Z6625-01-311-3742
and
MODEL 4220-S/4
N00104-89-D-0053
7Z6625-01-310-0802

THIS MANUAL APPLIES TO UNITS WITH SERIAL NUMBERS 41002BG AND ABOVE.

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BOONTON ELECTRONICS CORPORATION
INSTRUCTION MANUAL-SUPPLEMENT: MODEL 4220-S/3 AND 4220-S/4

OCTOBER, 1989

The following items are part of the S/3 and S/4 Configurations and are not contained in the Replaceable Parts List.

4220-S/3

Description	Fed. Code	Manufacturer Model Number	Qty.	BEC Part Number
Power Sensor	04901	51100-9E-S/1	1	95110093A
Power Sensor	04901	51013-4E-S/21	1	94002602A
Sensor Cable	04901	41-2A	2	09170501A
Transit Case	04901		1	95005401A

4220-S/4

Description	Fed. Code	Manufacturer Model Number	Qty.	BEC Part Number
Power Sensor	04901	51063-9E-S/1	1	95106391A
Power Sensor	04901	51033-6E	1	95103304A
Sensor Cable	04901	41-2A	2	09170501A
Transit Case	04901		1	95005401A

SENSOR CHARACTERISTICS

Model (Impedance) (RF Connector)	Freq. Range	PWR range (Watts) (dBm)	Overload Rating (Watts) (dBm)	Max. SWR		Drift and Noise Lowest Range		
				Frequency	SWR	Drift(typical) 1 Hr**	Noise(typical) RMS	2σ
DIODE SENSORS								
51013-4E-S/21 50 ohms N(M)	100kHz to 18GHz	1.0nW to 100mW -60 to +20dBm	300mW +25dBm	100kHz to 18GHz	1.40	150pW	65pW	130pW
51033-6E 50 ohms N(M)	100kHz to 18GHz	100nW to 2W -40 to +33dBm	2W +33dBm	100kHz to 1GHz 1GHz to 2GHz 2GHz to 4GHZ 4GHz to 12.4GHz 12.4GHz to 18GHz	1.07 1.10 1.12 1.18 1.28	15nW	6.5nW	13nW
THERMOCOUPLE SENSORS								
51100-9E-S/1 50 ohms N(M)	10MHz to 18GHz	1.0uW to 100mW -30 to +20dBm	300mW +25dBm*	10MHz to 18GHz	1.40	200nW	100nW	200nW
51063-9E-S/1	100kHz to 4.2GHz	1mW to 3W 0 to +35dBm	3.5W (Avg) 100Wpk 100Wus	100KHz to 4.2GHz	1.30	20uW	10uW	20uW

(see page 1-4 for NOTES)

SAFETY SUMMARY

The following general safety precautions must be observed during all phases of operation and maintenance of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. Boonton Electronics assumes no liability for the customer's failure to comply with these requirements.

THE INSTRUMENT MUST BE GROUNDED

To minimize shock hazard the instrument chassis and cabinet must be connected to an electrical ground. The instrument is equipped with a three conductor, three prong a.c. power cable. The power cable must either be plugged into an approved three-contact electrical outlet or used with a three-contact to a two-contact adapter with the (green) grounding wire firmly connected to an electrical ground at the power outlet.

DO NOT OPERATE THE INSTRUMENT IN AN EXPLOSIVE ATMOSPHERE.

Do not operate the instrument in the presence of flammable gases or fumes.

KEEP AWAY FROM LIVE CIRCUITS.

Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified maintenance personnel. Do not replace components with the power cable connected. Under certain conditions dangerous voltages may exist even though the power cable was removed; therefore, always disconnect power and discharge circuits before touching them.

DO NOT SERVICE OR ADJUST ALONE.

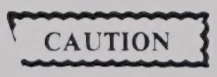
Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT.

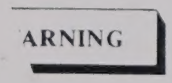
Do not install substitute parts or perform any unauthorized modification of the instrument. Return the instrument to Boonton Electronics for repair to ensure that the safety features are maintained.

SAFETY SYMBOLS

This safety requirement symbol (located on the rear panel) has been adopted by the International Electrotechnical Commission, Document 66 (Central Office) 3, Paragraph 5.3, which directs that the instrument be so labeled if, for the correct use of the instrument, it is necessary to refer to the instruction manual. In this case it is recommended that reference be made to the instruction manual when connecting the instrument to the proper power source. Verify that the correct fuse is installed for the power available, and that the switch on the rear panel is set to the applicable operating voltage.



The CAUTION sign denotes a hazard. It calls attention to an operation procedure, practice, or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the equipment. Do not proceed beyond a CAUTION sign until the indicated conditions are fully understood and met.



The WARNING sign denoted a hazard. It calls attention to an operation procedure, practice, or the like, which, if not correctly performed or adhered to, could result in injury or loss of life. Do not proceed beyond a WARNING sign until the indicated conditions are fully understood and met.

Indicates dangerous voltages.

BOONTON ELECTRONICS CORPORATION
INSTRUCTION MANUAL-SUPPLEMENT: MODEL 4220-S/3 AND 4220-S/4

OCTOBER, 1989

Instruction-manual supplements are issued as required to correct errors in a manual, and to adapt the manual to changes made after its printing.

1. Replace paragraph 2-14.f. with the following:

   Verify that "FrE" is shown on the dB CAL FACTOR display, and "OFF" is shown on the main data display. The main data display can be incremented and decremented using the up/down keys.

2. Add the following sentence to paragraph 3-12.b:

   "OFF" is shown on the main data display if no frequency value has been entered.

3. In paragraph 3-26. under the **Default Value** column add the word **"OFF"** after 0.00 GHz.

4. Add the following column to the right of "Model No." in TABLE 6-1 Test Equipment List.

Item No.*	Minimum Use Specifications	
1	Frequency Range	: DC-100MHz
	Sensitivity	: .01 V/Div
2	Voltage Range	: 100mV to 100V
	Resolution	: 1mV
	Accuracy	: 0.01%
3	Output	: 9, 90, 900 uV 9, 90, 900 mv and 4.5V balanced
	Accuracy	: 9uV ±1% 90uV ± .4% All others ± .2%
	Output Impedance	: 500K
4	Accuracy	: .01%
	Frequency Range	: 10 Hz to 100 MHz
5	Accuracy	: .015 dB
	Frequency	: DC to 300 MHz
	Level	: 0.00 dBm

Item No.*	Minimum Use Specifications		
6	Connectors	:	Type N
	Resolution	:	50 ohms ± 1%
	Frequency	:	DC to 1 GHz
7	Frequency	:	30 MHz ± 0.1%
	Level	:	-70 to +20 dBm in 0.1 dB steps into 50 ohms
	VSWR	:	1.05
	Impedance	:	50 ohms

*Provided for reference only and is not part of the new column

5. Replace paragraphs 6-15 through 6-20 with the following:

6-15. 4220 Performance Tests

6-16. Perform the following tests on an annual basis or as frequently as required to verify proper instrument operation.

6-17. Perform the Preliminary Checks listed in section 2-14 a through z.

6-18. Calibration Accuracy Test.

a. Connect a sensor to the 4220.
b. Select the Sensor Number for the sensor to be tested and verify that the sensor model and serial number are correct.
c. Connect Boonton coaxial sensors to a Boonton model 2520 RF calibrator, or equivalent. If the sensor is a waveguide sensor, connect it to some other accurate and stable RF signal source.
d. The frequency of the Boonton model 2520 RF calibrator is fixed at 30 MHz which is the reference frequency for Boonton coaxial sensors. For waveguide sensors, set the frequency of the RF signal source to the reference frequency listed in tables 1-3 and 1-4.
e. Set the 4220 to dBm Display mode.
f. Set the calibrator to -70.0 dBm, OUTPUT OFF.
g. Allow warm up and settling time of at least 15 minutes.
h. Press the ZERO key on the 4220. Verify a zero acquisition. The 'LO' message should appear on the display.
i. Adjust the calibrator output to each of the power levels listed in table 6-1.A. or 6-1.B. Tabulate the 4220's displayed readings versus calibrator output levels.

j. Verify that the 4220 readings agree with the calibrator output level to within the required accuracy. Calculate the required accuracy of the reading for each dBm level as follows:

ACCURACY = TABLE ENTRY + SOURCE ERROR + SHAPING ERROR

The TABLE ENTRY is listed in table 6-1.A. or 6-1.B. for each power level.

The SOURCE ERROR for the Boonton 2520 is listed in table 6-1.A. for each power level. For the Boonton 25A the SOURCE ERROR is .05 dB for all levels. Consult the specification sheets of other manufacturer's RF signal sources for their source errors.

The 4220 SHAPING ERROR is typically .04 dB. See Table 1-2 notes.

6-19. 50 MHz Calibrator Performance Tests

6-20. The 50 MHz 0dBm calibrator is checked using a Wandel & Goltermann model EPM-1 Milliwatt Test Set, or equivalent National Institute of Standards and Technology (NIST) traceable power meter. NIST was formerly the National Bureau of Standards (NBS).

The procedure is as follows:

a. Allow the equipment to warm up and stabilize for 30 minutes. The 4220 "CAL" annunciator should be set on.
b. Connect the EPM-1 thermistor power head to the 0 dBm output port on the EPM-1 test set. Adjust per the manufacturers instructions for a 0 dBm reading on the analog meter.
c. Disconnect the thermistor power head from the EPM-1 test set and connect it to the 4220 50 MHz calibrator.
d. Observe the EPM-1 analog meter. The indication should be 0 dBm +/- .05 dB.
e. Disconnect the EPM-1.
f. Measure the output frequency of the 50 MHz calibrator. It should be 50 MHz +/- 0.75 MHz.

Table 6-1.A. Calibration Accuracy for Coaxial Sensors

Power Level dBm	----------LIMITS FOR SENSOR MODELS IN dB----------					
	51012 51011 51013	51051	51015	51033	51100	Model 2520 Source Error dB
-60	0.75	0.40				0.17
-55	0.40	0.20				0.11
-50	0.20	0.11	0.75			0.11
-45	0.09	0.09	0.40			0.11
-40	0.09	0.09	0.20	0.75		0.07
-35	0.06	0.06	0.09	0.40		0.07
-30	0.06	0.06	0.07	0.20	0.90	0.07
-25	0.06	0.06	0.06	0.09	0.32	0.07
-20	0.06	0.06	0.06	0.06	0.13	0.07
-15	0.06	0.06	0.06	0.06	0.07	0.07
-10	0.06	0.06	0.06	0.06	0.05	0.07
- 5	0.06	0.06	0.06	0.06	0.05	0.07
0	0.04	0.04	0.04	0.04	0.04	0.05
+ 5	0.06	0.06	0.06	0.06	0.05	0.07
+10	0.06	0.06	0.06	0.06	0.04	0.07
+15	0.06		0.06	0.06	0.05	0.07
+20	0.06		0.06	0.06	0.04	0.07
+25			0.08	0.08		
+30			0.09	0.09		
+33				0.10		

Table 6-1.B. Calibration Accuracy for Waveguide Sensors

dBm Level	----------LIMITS FOR SENSOR MODELS IN dB----------					
	51035 51036 51072	51037 51045	51046 51047			
-50	0.75	0.80	0.90			
-45	0.62	0.75	0.82			
-40	0.50	0.70	0.71			
-35	0.42	0.62	0.66			
-30	0.36	0.56	0.61			
-25	0.31	0.51	0.56			
-20	0.26	0.46	0.51			
-15	0.31	0.51	0.56			
-10	0.36	0.56	0.61			
- 5	0.41	0.61	0.66			
0	0.46	0.66	0.71			
+ 5	0.51	0.71	0.76			
+10	0.56	0.76	0.81			

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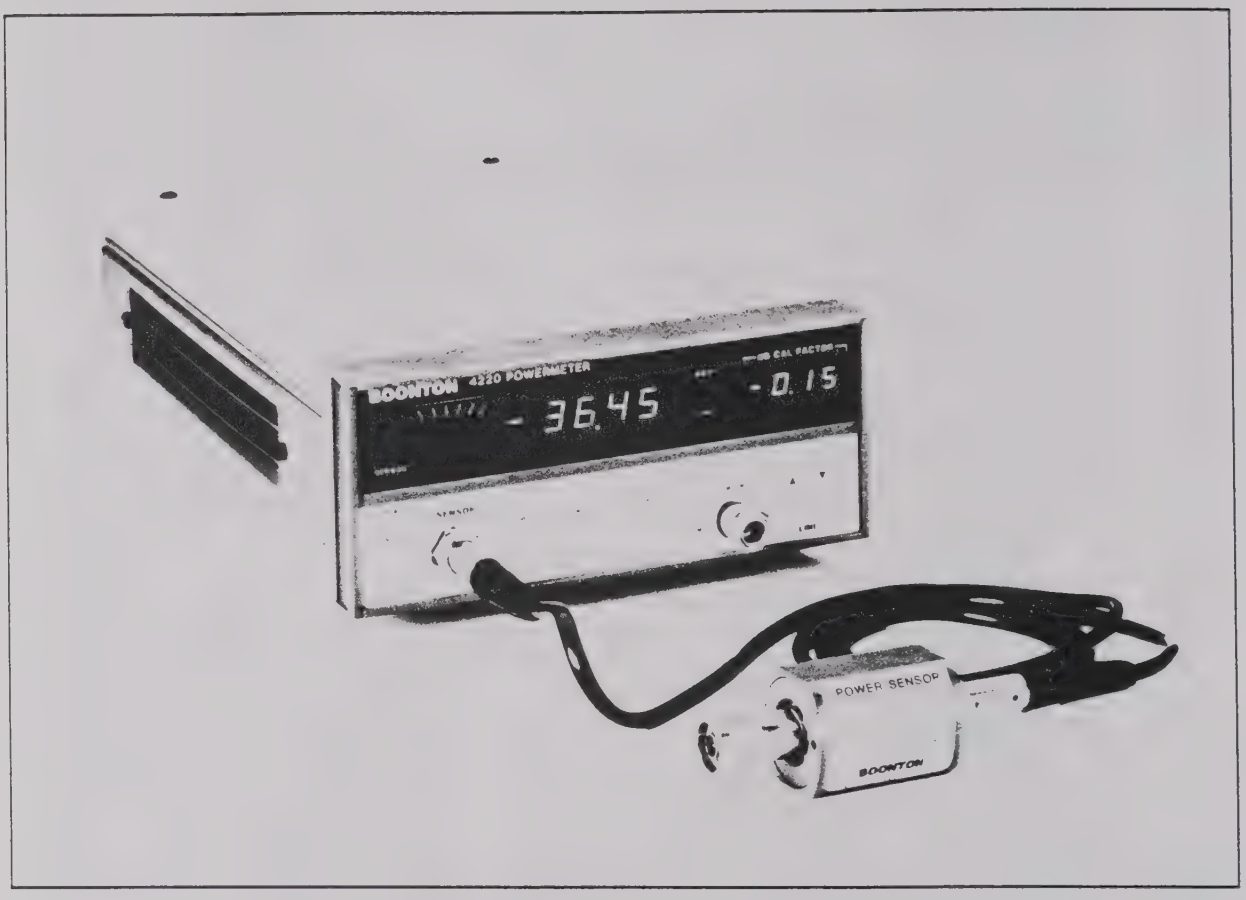

Figure 1-1. Model 4220 RF Powermeter.

SECTION I
GENERAL INFORMATION

1-1. INTRODUCTION.

1-2. This instruction manual provides general information, installation and operating instructions, application notes, theory of operation, maintenance instructions, parts lists, and schematic diagrams for the Model 4220 RF Powermeter. See Figure 1-1 and 1-2.

1-3. DESCRIPTION.

1-4. The Model 4220 is a microprocessor-based, single channel, solid state RF powermeter. It is capable of measuring RF power levels from -75 dBm to +50 dBm. The frequency range and power level are sensor dependent. Available Boonton 50G00 series sensors provide measurement capabilities for frequencies from 100 kHz to 110 GHz.

1-5. FEATURES.

1-6. Power Sensors. A wide range of diode and thermocouple power sensors for both coaxial and waveguide applications is available for use with the Model 4220. Power sensors are not supplied as part of the Model 4220, but must be ordered separately.

1-7. Diode sensors measure the voltage across a precision resistor, using specially selected diodes. Detection is square law (true RMS) over approximately the lower two-thirds of the sensor dynamic range, and peak detecting over the upper portion. Because the instrument is calibrated for sine waves over the entire range, measurements at the top one-third of the sensor dynamic range are valid only for non-modulated signals. In the RMS region, linearity is excellent, and any signal type can be measured. The diode range has been extended into the peak detecting region with the use of real time shaping for the diode curve. When coupled with the high sensitivity of the diode, such shaping allows an unprecedented dynamic range of 80 dB or more. Diode sensors are rugged and have an overload headroom of more than 5 dB for continuous signals. The dynamic range in the RMS region can be extended further through use of an external attenuator.

1-8. Thermal sensors measure the voltage developed across a dissimilar metal junction caused by the thermal gradient generated by the RF power being measured. Because these sensors are heat detecting, they provide true RMS response over their entire range. Very high peak power (15 to 30 watts) can be accommodated for very short duty cycles and still provide valid results. The dynamic range is 50 dB. Thermal sensors are not as sensitive as diode sensors.

1-9. Calibration data for up to four sensors can be stored in non-volatile RAM. Linearity and high frequency sensor calibration correction data, which are supplied with each sensor, can be entered. For sensors ordered with the Model 4220, the calibration data is entered prior to shipment. When the frequency of the RF signal to be measured by one of these sensors is entered, the instrument looks up the appropriate high frequency calibration factors (cal factors), interpolates as necessary, and applies the correction to the measured value automatically. Sensors for which cal factors are not stored in RAM can also be used with the instrument. Cal factors for such sensors can be read off the calibration sheet supplied with the sensor and entered manually through the front panel controls. Cal factors entered in this manner will be used by the instrument to correct subsequent readings, but will not be stored in non-volatile RAM. Cal factors for sensors ordered with the instrument are stored in a plastic pouch attached to the inside top cover.

1-10. Simple Instrument Setup and Operation. In the operating mode the functions ZERO, WATTS, dBm, dBr, LOAD REF, and PWR REF are selected with a single keystroke. In the shifted mode, GPIB address, filter, frequency, range, set reference, and sensor calibration setup parameters may be accessed. Values for these parameters are displayed and can be adjusted simply by using up/down keys.

1-11. Alphanumeric Displays. Two alphanumeric LED displays provide clear, unambiguous readouts of instrument setup and measurement values. In the shifted mode, selected setup functions are shown on one of the displays and the numerical value for that function is shown on the other. In the operating mode, the measured value is shown on one of the displays, and the dB calibration factor applied to the measurement is shown on the other. Annunciators associated with the main data display indicate the unit applicable to the displayed measurement value, thereby minimizing the possibility of reading misinterpretation.

1-12. Selectable Ranging. Any of seven measurement ranges, or autoranging, can be selected during instrument setup. The selection will be held until it is changed, or until the instrument is off. When measuring signals with levels that fall within a narrow range, selecting one specific instrument range may reduce measurement time. Autoranging is useful if the RF signal level is unknown, or if RF signals with widely varying levels are to be measured.

1-13. Selectable Filtering. Measurement speed and display stability can be optimized through the use of selectable filtering. Filter times can be adjusted up to 20 seconds maximum in 50 millisecond increments.

1-14. Zeroing. Automatic zeroing (nulling of offsets for the sensor and input channel) is done independently on each range to eliminate zero carryovers.

1-15. Built-In Precision Calibrator. A built-in 50 MHz calibrator provides an accurate, stable, and convenient power source for calibration of the instrument to specified tolerances. The calibrator may be toggled on or off using the front panel PWR REF key.

1-16. Analog Display. A front panel meter provides an analog display of measured values. This feature is especially useful for nulling and peaking applications.

1-17. Chart Recorder Output. A 0 to 10 volt dc output, proportional to the measurement values, is available for application to a chart recorder.

1-18. GPIB (Optional). An IEEE-488 option enables full service remote control of the Model 4220. All instrument controls and values, except power on and off, are accessible to a bus controller in the remote operating mode.

1-19. ACCESSORIES.

1-20. The AC power cord is supplied with the instrument. One or more Boonton 50000 series power sensors are required. The power sensors are not supplied as part of the instrument, but must be ordered separately. A five-foot power sensor cable, Model 41-2A, is supplied with each sensor ordered. Additional available accessories include the following:

a. Model 41-2A/10 Sensor/Probe Interconnecting Cable (10 ft)

b. Model 41-2A/20 Sensor/Probe Interconnecting Cable (20 ft)

c. Model 41-2A/50 Sensor/Probe Interconnecting Cable (50 ft)

d. Model 41-2A/100 Sensor/Probe Interconnecting Cable (100 ft)

e. Model 950047 F/F Adapter, 41-2A (for connecting Model 41-2A cables end to end)

f. Model 950049 Bulkhead Connector F/F, 41-2A (for connecting Model 41-2A cables end to end)

g. Model 954015 Rack Mounting Kit

1-21. OPTIONS.

1-22. An IEEE-488 bus option is available for remote operation of the instrument in ATE applications. SH1, AH1, T6, L4, SR1, RL1, DC1, and DT1 are all implemented.

1-23. SPECIFICATIONS.

1-24. Performance specifications of the Model 4220 are listed in Table 1-1.

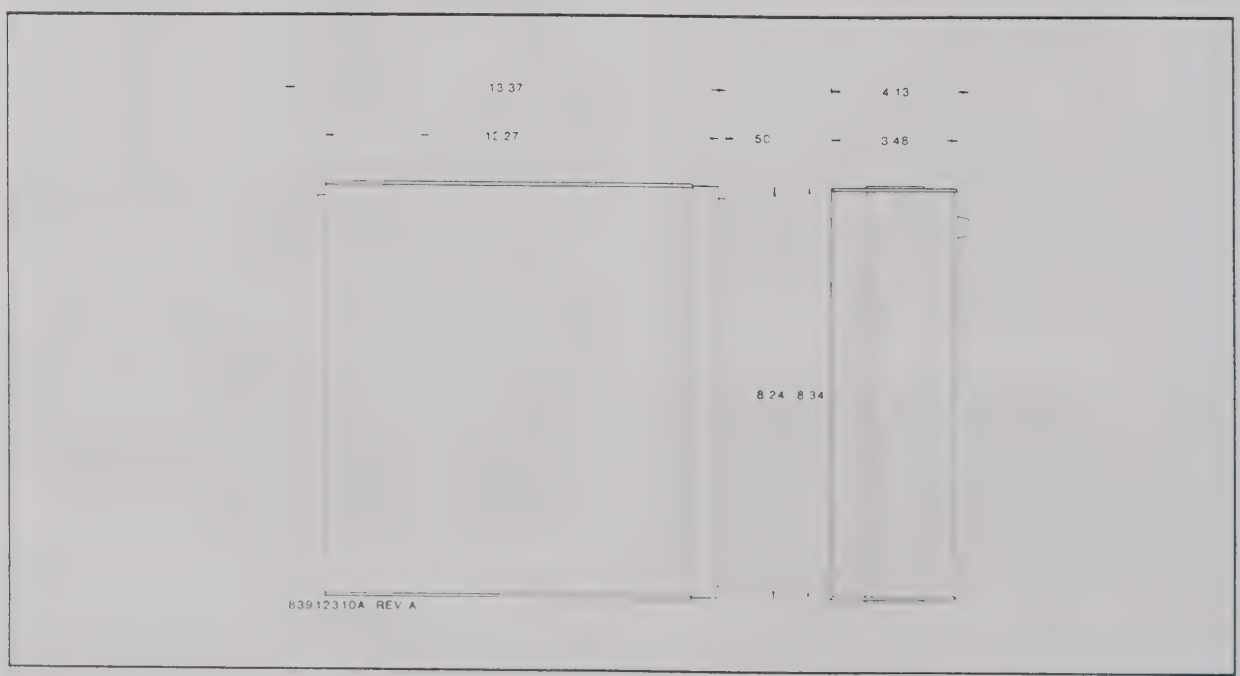

Figure 1-2. Outline Dimensions.

TABLE 1-1. PERFORMANCE SPECIFICATIONS

Parameter	Specification
Frequency Range	100 kHz to 110 GHz, sensor dependent
Power Range	-70 dBm to +33 dBm, sensor dependent
Power Sensors	Compatible with all Boonton diode and thermal sensors (refer to Table 1-2)
Dynamic Range	Up to 80 dB with diode sensors; up to 50 dB with thermal sensor
Inputs	Front panel SENSOR connector; rear panel IEEE-488 connector optional
Outputs	Front panel PWR REF connector, 50 MHz, 0 dBm; rear panel recorder BNC connector, 9.09 kilohm impedance, 0 to 10 volts into 1 megohm (may be operated into 1 kilohm for 1V fs)
Displays:	
Main data	4-1/2 digit LED
dB CAL FACTOR	4 digit LED
Analog	Meter, reading proportional to main data display
Display Units	W, mW, µW, nW, dBm, dBr
Display Resolution	0.01 dB or 4-1/2 digits
Ranging	Manual (7 ranges) or autoranging
Filtering	Filter times to 20.00 seconds in 0.05 second increments
Zeroing	Automatic function; calculates, stores, and applies zero corrections to each range
High Frequency Cal Factors:	+3 dB to -3 dB in 0.01 dB steps; cal factors for up to four power sensors with up to 36 frequencies each may be stored in non-volatile memory
Reference Level	-99.99 dB to +99.99 dB in 0.01 dB steps for dBr measurements
Power Reference:	
Frequency	50 MHz ± 1.5%
Output Level	0 dBm
Level Accuracy	±0.7% (±0.03 dB) (23 degrees C) for 90 days; ±0.9% (±0.04 dB) RSS, ±1.2% (±0.05 dB) worst case (0 to 55 degrees C) for 1 year
Source Impedance	50 ±1 ohm
VSWR	< 1.02
Harmonic Output	< -60 dBc
Measurement Accuracy	Sum of following uncertainties (errors are ± worst case): instrument uncertainty, noise/signal percentage, power reference uncertainty, sensor shaping, temperature drift, and high frequency calibration factors
Instrument Uncercertainty	±0.47% (±0.02 dB) at full scale; ±0.69% (±0.03 dB) at 1/10 full scale
Noise/signal Percentage	Convert noise listed in Table 1-2 to percent of full scale
Power Reference Uncertainty	Refer to Table 1-5
Sensor Shaping	±1.0% (±0.04 dB)
Temperature Drift	Refer to Table 1-6
High Frequency	
Calibration Factors	Refer to Table 1-3 or 1-4, as applicable
Power Requirements	100, 120, 220, or 240 VAC, 50-60 Hz or 400 Hz, 40 VA maximum
Operating Temperature	0 to 55 degrees C
Weight	6.6 lb (0.66 kg)
Dimensions	3.5 in. H, 8.25 in. W, 13.25 in. D (8.9 X 21.0 X 33.7 cm)

TABLE 1-2. SENSOR CHARACTERISTICS

Model (Impedance) (RF Connector)	Freq. Range	PWR range (Watts) (dBm)	Overload Rating (Watts) (dBm)	Max. SWR		Drift and Noise Lowest Range		
				Frequency	SWR	Drift (typical) 1 Hr**	Noise (typical) RMS	Noise (typical) 2σ
DIODE SENSORS								
51011 (4B) 50Ω N(M)	100 kHz to 12.4 GHz	1.0 nW to +100 mW −60 to +20 dBm	300 mW +25 dBm	100 kHz to 2 GHz 2 GHz to 4 GHz 4 GHz to 11 GHz 11 GHz to 12.4 GHz	1.12 1.2 1.4 1.6	150 pW	65 pW	130 pW
51012 (4C) 75Ω N(M)	100 kHz to 1 GHz	1.0 nW to +100 mW −60 to +20 dBm	300 mW +25 dBm	100 kHz to 1 GHz	1.18	150 pW	65 pW	130 pW
51013 (4E) 50Ω N(M)	100 kHz to 18 GHz	1.0 nW to 10 mW −60 to +20 dBm	300 mW +25 dBm	100 kHz to 4 GHz 4 GHz to 10 GHz 10 GHz to 18 GHz	1.3 1.5 1.7	150 pW	65 pW	130 pW
51051 (4G) 50Ω APC 3.5 (M)	1 MHz to 26.5 GHz	0.1 nW to 10 mW −70 to +10 dBm	300 mW +25 dBm	1 MHz to 12.4 GHz 12.8 GHz to 18 GHz 18 GHz to 26.5 GHz	1.28 1.37 1.92	100 pW	30 pW	60 pW
51015 (5E) 50Ω N(M)	100 kHz to 18 GHz	10 nW to 1 W −50 to +30 dBm	2 W +33 dBm	100 kHz to 1 GHz 1 GHz to 2 GHz 2 GHz to 4 GHz 4 GHz to 12.4 GHz 12.4 GHz to 18 GHz	1.07 1.10 1.12 1.18 1.28	1.5 nW	.65 nW	1.3 nW
51033 (6E) 50Ω N(M)	100 kHz to 18 GHz	100 nW to 2 W −40 to +33 dBm	2 W +33 dBm	100 kHz to 1 GHz 1 GHz to 2 GHz 2 GHz to 4 GHz 4 GHz to 12.4 GHz 12.4 GHz to 18 GHz	1.07 1.10 1.12 1.18 1.28	15 nW	6.5 nW	13 nW
THERMOCOUPLE SENSOR								
51100 (9E) 50Ω N(M)	10 MHz to 18 GHz	1.0 μW to 100 mW −30 to +20 dBm	300 mW +25 dBm*	10 MHz to 15 MHz 15 MHz to 10 GHz 10 GHz to 18 GHz	1.5 1.35 1.6	200 nW	100 nW	200 nW
* Thermocouple Pulse Characteristics at 25°C: Maximum pulse energy = 30 W-μsec. (per pulse) Maximum pulse power = 15 W Peak								
WAVEGUIDE SENSORS								
51035 (4K) WR-42 UG-595/U	18 GHz to 26.5 GHz	10 nW to 10 mW −50 to +10 dBm	100 mW +20 dBm	18 GHz to 26.5 GHz	1.3	200 pW	60 pW	120 pW
51036 (4KA) WR-28 UG-599/U	26.5 GHz to 40 GHz	10 nW to 10 mW −50 to +10 dBm	100 mW +20 dBm	26.5 GHz to 40 GHz	1.3	60 pW	15 pW	30 pW
51037 (4Q) WR-22 UG-383/U	33 GHz to 50 GHz	10 nW to 10 mW −50 to +10 dBm	100 mW +20 dBm	33 GHz to 50 GHz	1.3	60 pW	15 pW	30 pW
51045 (4U) WR-19 UG-383/U	40 GHz to 60 GHz	10 nW to 10 mW −50 to +10 dBm	100 mW +20 dBm	40 GHz to 60 GHz	1.3	60 pW	15 pW	30 pW
51046 (4V) WR-15 UG-385/U	50 GHz to 75 GHz	10 nW to 10 mW −50 to +10 dBm	100 mW +20 dBm	50 GHz to 75 GHz	1.3	60 pW	15 pW	30 pW
51047 (4W) WR-10 UG-387/U	75 GHz to 110 GHz	32 nW to 10 mW −45 to +10 dBm	100 mW +20 dBm	75 GHz to 110 GHz	1.3	60 pW	15 pW	30 pW
51972-WRD WRD180C24	18 GHz to 40 GHz	10 nW to 10 mW −50 to +10 dBm	100 mW +20 dBm	18 GHz to 40 GHz	1.3	200 pW	60 pW	120 pW

NOTES: * Will withstand short periods of overload, extended overload operation may result in permanent change in characteristics or burnout
** After 2 hour warmup

High frequency power linearity uncertainty: (worst case) 4B, 4C, 4E (.005 × f) dB per dB above +4 dBm; (above +14 dBm for the 5E and above +24 dBm for the 6E), where f is in GHz

Power Linearity Uncertainty At 50 MHz
<10 dBm: 1% for 4B, 4C, 4E, 5E, 6E, 9E, and all waveguide sensors, 2% for 4G sensor
10-20 dBm: 1% for 5E and 6E sensors; 3% for 4B, 4C, and 4E sensors. 20-33 dBm: 3% for 5E and 6E sensors

TABLE 1-3. CALIBRATION FACTOR UNCERTAINTY, COAXIAL SENSORS

Model	Frequency GHz																		
	.03-.05*	< 2	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19-26.5
4B (51011)																				
Max. %	0	1.3	3.0	3.0	3.5	3.5	3.5	3.5	4.0	4.0	4.0	4.5	4.5							
RSS %	0	1.3	1.7	1.7	1.7	1.8	1.9	2.0	2.1	2.5	2.5	2.4	3.0							
4C (51012)																				
Max. %	0	1.3																		
RSS %	0	1.3																		
4E (51013)																				
Max. %	0	1.3	3.0	3.0	3.5	3.5	3.5	3.5	4.0	4.0	4.0	4.5	4.5	6.0	6.0	6.0	6.0	6.0	6.0	
RSS %	0	1.3	1.8	1.8	1.8	1.9	2.0	2.0	2.2	2.6	2.5	2.7	3.0	3.4	3.1	3.2	3.3	3.1	3.4	
4G (51051)																				
Max. %	0	1.3	3.0	3.0	3.5	3.5	3.5	3.5	4.0	4.0	4.0	4.0	4.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0
RSS %	0	1.3	1.7	1.7	1.7	1.7	1.8	1.9	2.0	2.4	2.3	2.2	2.6	3.0	2.8	2.8	2.9	2.8	3.1	3.4
5E (51015)																				
Max. %	0	1.3	3.0	3.0	3.5	3.5	3.5	3.5	4.0	4.0	4.0	4.0	4.5	6.0	6.0	6.0	6.0	6.0	6.0	
RSS %	0	1.3	1.7	1.7	1.7	1.7	1.8	1.9	2.0	2.4	2.3	2.2	2.8	3.0	2.8	2.8	2.9	2.8	3.1	
6E (51033)																				
Max. %	0	1.3	3.0	3.0	3.5	3.5	3.5	3.5	4.0	4.0	4.0	4.0	4.5	6.0	6.0	6.0	6.0	6.0	6.0	
RSS %	0	1.3	1.7	1.7	1.7	1.7	1.8	1.9	2.0	2.4	2.3	2.2	2.8	3.0	2.8	2.8	2.9	2.8	3.1	
9E (51100)																				
Max. %	0	1.3	3.0	3.0	3.5	3.5	3.5	3.5	4.0	4.0	4.0	4.0	4.5	6.0	6.0	6.0	6.0	6.0	6.0	
RSS %	0	1.3	1.8	1.8	1.8	1.8	1.9	2.0	2.1	2.5	2.4	2.6	2.9	3.3	3.1	3.1	3.2	3.0	3.4	

* Reference Frequency = 50 MHz. Note: CAL Factors are supplied at every 1 GHz.

TABLE 1-4 CALIBRATION FACTOR UNCERTAINTY, WAVEGUIDE SENSORS

Model	Ref. GHz	At Ref. Freq.	Over Sensor BW	Sensor	Ref. GHz	At Ref. Freq.	Over Sensor BW	Sensor	Ref. GHz	At Ref. Freq.	Over Sensor BW	Sensor	Ref. GHz	At Ref. Freq.	Over Sensor BW
4K (51035)	22			4Q (51037)	40			4V (51046)	60						
Max. %		6	6	Max. %		10	13	Max. %		12	13	WRD-180 (51972)	33		
RSS %		5	5	RSS %		6	7	RSS %		6	9				
4KA (51036)	33			4U (51045)	40			4W (51047)	94			Max. %		6	10
Max. %		6	10	Max. %		10	13	Max. %		12	13	RSS %		5	7
RSS %		5	7	RSS %		6	8	RSS %		9	11				

Note: For waveguide sensors, the reference calibration is at −20 dBm. For levels other than −20 dBm there is an additional uncertainty of 0.01 dB per dB relative to −20 dBm

TABLE 1-5. POWER REFERENCE UNCERTAINTY

Model	Uncertainty
All coaxial sensors	±0.7% (±0.03 dB) at 0 dBm for 90 days
51035	0.25 dB + 0.01 dB per dB relative to -20 dBm
51036, 51037, 51045, 51046, and 51047	0.50 dB + 0.01 dB per dB relative to -20 dBm

TABLE 1-6. TEMPERATURE COEFFICIENT

Model	Temperature Coefficient
51013, 51015, and 51033	0.015 dB per degree C from 18 to 28 degrees relative to 23 degrees C
51051	0.05 dB per degree C from 18 to 28 degrees relative to 23 degrees C

SECTION II
INSTALLATION

2-1. INTRODUCTION.

2-2. This section contains unpacking, mounting, power requirements, connections, and preliminary checkout instructions for the Model 4220.

2-3. UNPACKING.

2-4. The Model 4220 is shipped complete and is ready for use upon receipt. Packaging details are shown in Figure 2-1. Unpack the instrument from the shipping container and inspect it for damage that may have occurred during shipment.

NOTE

Save the packing material and container for possible use in shipment of the instrument.

2-5. MOUNTING.

2-6. For bench-top use, choose a clear, uncluttered area. A pull down bail is at the bottom of the instrument for use as needed. For rack mounting, an accessory kit is available. The required hardware and instructions are supplied with the accessory kit.

2-7. POWER REQUIREMENTS.

2-8. The Model 4220 has a tapped power transformer and two line switches that permit operation from 100, 120, 220, or 240 volt, 50 to 60 Hz or 400 Hz, single-phase, AC power sources. (For operation using a 400 Hz power source, the trace between terminals E2 and E3 on input board A6 must be cut and a jumper must be connected between terminals E1 and E3 to establish a phase lock reference.) Power consumption is 40 VA maximum. An AC power cord is supplied with the instrument. Connect the power cord to the power receptacle on the rear panel of the instrument.

CAUTION

Before connecting the instrument to the power source, always make certain that the line voltage switches on the rear panel are set to the positions corresponding to the voltage of the AC power source, and that a slo-blow fuse of the correct rating (0.3 ampere for 100 or 120 volts, 0.15 ampere for 220 or 240 volts) is installed in the fuse holder.

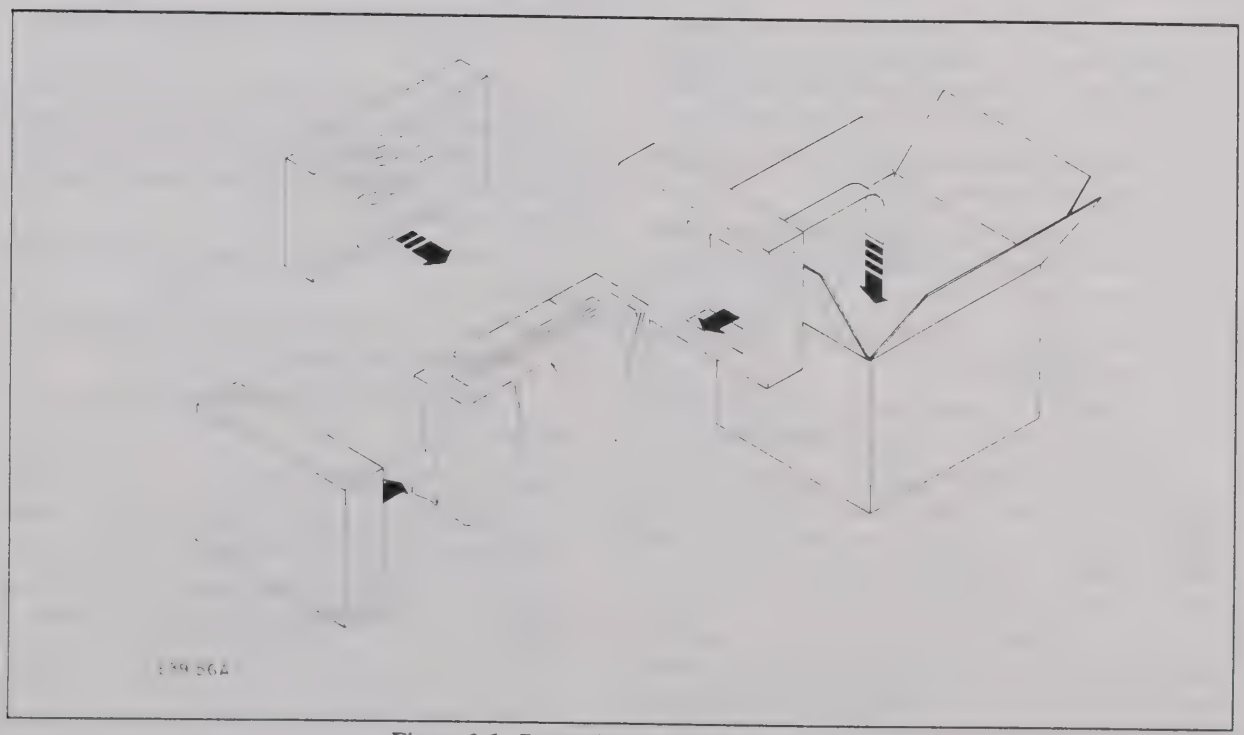

Figure 2-1. Packaging Diagram

2-9. CONNECTIONS.

2-10. Sensor. Connect the sensor that is to be used for the measurement to the front panel SENSOR connector using the cable supplied with the sensor or an accessory sensor/probe interconnecting cable.

2-11. Recorder. If a recorder is to be used to record measurement data, connect the recorder to the recorder BNC connector on the rear panel. Output impedance is 9.09 kilohms, and the output voltage range is 0 to 10 volts dc.

2-12. GPIB. If the instrument is equipped with the IEEE-488 option and it is to be operated remotely over the bus, connect the instrument to the bus via the rear panel IEEE-488 connector. The connector provides IEEE-488 standard interface.

2-13. PRELIMINARY CHECK.

2-14. The following preliminary check verifies that the Model 4220 is operational. It should be performed before the instrument is placed into use. To perform the preliminary check, proceed as follows:

a. Connect the AC power cord to the power receptacle at the rear of the instrument and to a suitable AC power source.

b. Set the front panel LINE switch to the ON position. The LINE annunciator should light, and the instrument should perform an initialization routine. During this routine, verify that the following events occur in the order given:

(1) All front panel display segments and all annunciators should be illuminated.

(2) "BEC" should be shown in the left display, and the number of the current software version should be shown in the right display.

(3) The nW, CAL, LINE, and SENSOR 1 annunciators should remain lighted.

(4) The main data display and the dB CAL FACTOR display should indicate some numerical values.

c. Using the SENSOR SELECT key, verify that the SENSOR 1, 2, 3, and 4 annunciators light in sequence. (If calibration data for sensors has been stored in non-volatile RAM, the sensor serial number and model should also be displayed during sensor selection.)

d. Press the ENTER/SHIFT key. Verify that four dashes are shown on the main data display, "SHFt" is shown on the dB CAL FACTOR display, and all annunciators except the LINE annunciator are off.

e. Press the FILTER/WATTS key. Verify that "FIL" is shown on the dB CAL FACTOR display, and the main data display can be incremented and decremented using the up/down keys.

f. Press the FREQ/dBm key. Verify that "FrE" is shown on the db CAL FACTOR display, and the main data display can be incremented and decremented using the up/down keys.

g. Press the RANGE/dBr key. Verify that "rg" is shown on the dB CAL FACTOR display, and the main data display can be incremented and decremented using the up/down keys.

h. Press the SET/LOAD REF key. Verify that "SEt" is shown on the dB CAL FACTOR display, and the main data display can be incremented and decremented using the up/down keys.

i. Press the CAL/PWR REF key. Verify that "rEF" is shown on the main data display, and "CAL" is shown on the dB CAL FACTOR display.

j. Press the RANGE/dBr key, then press the ENTER/SHIFT key. Verify that the CAL, LINE, nW, and SENSOR 1 annunciators are lighted, and some numerical value is displayed on each of the two displays.

k. Connect a sensor to the front panel SENSOR connector.

l. Press the ADRS/ZERO key. Verify that a series of brackets and dashes is shown on each of the two displays while the instrument performs the zeroing routine, and numerical values are displayed on both displays when zeroing has been completed.

m. Press the FREQ/dBm key and verify that the dBm annunciator lights.

n. Press the FILTER/WATTS key and verify that one of the power annunciators lights.

o. Press the RANGE/dBr key and verify that the dBr annunciator lights.

p. Press the FREQ/dBm key.

q. Connect the sensor to the 0 dBm 50 MHz connector on the front panel of the instrument.

r. Verify that the CAL annunciator is lit. If it is not, press the CAL/PWR REF key to actuate the calibrator.

s. Press the ENTER/SHIFT key, then the CAL/PWR REF key, and then the ENTER/SHIFT key again. The instrument should perform a calibration routine. At the completion of this routine, verify that the main data display shows 0.00 dBm.

t. Press the FILTER/WATTS key and verify that the main data display shows approximately 1000 uW.

u. Using a digital multimeter, verify that the voltage at the rear panel recorder connector is 10 volts dc.

v. Press the SET/LOAD REF key and verify that the main data display reading is approximately zero, the dBr annunciator lights, and the analog meter is centered.

w. Using a digital multimeter, verify that the voltage at the rear panel recorder connector is 8.0 volts dc.

x. Disconnect the sensor from the 0 dBm 50 MHz connector.

y. Verify that the dB CAL FACTOR display can be incremented and decremented using the up/down keys.

z. If the specified results have been obtained in each of the preceding steps, the instrument can be placed into service.

SECTION III
OPERATION

3-1. INTRODUCTION.

3-2. This section contains operating instructions for the Model 4220. It is strongly recommended that the operator become familiar with all the material in this section and with the application notes in Section IV before attempting to operate the instrument; otherwise, the full capabilities of the instrument may not be realized.

3-3. OPERATING CONTROLS, INDICATORS, AND CONNECTORS.

3-4. See Figures 3-1 and 3-2 for the location of the operating controls, indicators, and connectors. Refer to Table 3-1 for the function of each of these items. Note that most of the keys on the front panel have two designations, one in blue and the other in black. These keys perform different functions in the shifted mode (blue) and the normal operating mode (black). Switching from the operating mode to the shifted mode occurs when the ENTER/SHIFT key is pressed. The shifted mode is used to set up the instrument parameters for the measurements to be made. Instrument parameters may be viewed in the shifted mode without altering their values. When the ENTER/SHIFT key is pressed again, the currently displayed parameter value is entered, and the instrument is returned to the operating mode.

NOTE

The instrument will display "Err" and an error code when operating conditions are violated. (Refer to Table 4-6 for error codes.) In the operating mode, errors are cleared by pressing the WATTS, dBm, dBr keys. In the shifted mode, errors are cleared by pressing the ENTER key, which returns the instrument to the operating mode.

3-5. OPERATING THE INSTRUMENT.

3-6. Energize the instrument by setting the LINE switch to the ON position. The LINE annunciator will light, and the

TABLE 3-1. OPERATING CONTROLS, INDICATORS, AND CONNECTORS

Index and Fig. No.	Nomenclature	Function
1, 3-1	(LOCAL)/SENSOR SELECT key	If the instrument is operating in the remote bus mode (option), pressing this key restores local control; in the local mode, this key selects one of four sensors for which calibration data is stored in the instrument. Pressing this key selects the next sensor number and, as long as the key is held, displays the sensor serial number and sensor model.
2, 3-1	SENSOR annunciators	Display the number of the sensor (1 through 4) selected by the SENSOR SELECT key.
3, 3-1	Analog meter	Provides an analog display of the measured power level for nulling or peaking applications.
4, 3-1	Main data display	4-1/2 digit LED display: in the operating mode, displays measured values; in the shifted mode, displays numerical values of selected parameters.
5, 3-1	Main display annunciators	Lighted measurement unit annunciators indicate the unit of measurement; CAL annunciator indicates that the 50 MHz calibrator is on; LINE annunciator indicates that instrument power is turned on.
6, 3-1	Bus annunciators	On instruments equipped with the IEEE-488 option, indicate bus activity.
7, 3-1	dB CAL FACTOR	4 digit LED display: in the operating mode, displays the sensor calibration factor being applied to measured values; in the shifted mode, shows the parameter selected for observation or adjustment.

TABLE 3-1. OPERATING CONTROLS, INDICATORS, AND CONNECTORS (Cont.)

Index and Fig. No.	Nomenclature	Function
8, 3-1	Up/down keys	Provide means for adjustment of selected parameter values in the shifted mode, and the sensor calibration factor in the operating mode.
9, 3-1	LINE switch	Turns the instrument on and off.
10, 3-1	CAL/PWR REF key	In the shifted mode, initiates an internal calibration routine; in the operating mode, toggles the 50 MHz calibrator on and off.
11, 3-1	0 dBm 50 MHz connector	Provides a 50 MHz, 0 dBm output for instrument calibration when the CAL annunciator is lighted. When off, connector can be used to zero the instrument.
12, 3-1	SET/LOAD REF key	In the shifted mode, selects the reference level for dBr measurements as the parameter to be displayed and/or adjusted; in the operating mode, loads the current measurement value (in dBm) as the reference level for dBr measurements.
13, 3-1	RANGE/dBr	In the shifted mode, selects the instrument measurement range for display and/or adjustment; in the operating mode, selects dBr as the unit of measurement.
14, 3-1	FREQ/dBm key	In the shifted mode, selects the frequency of the measurement signal as the parameter to be displayed and/or adjusted; in the operating mode, selects dBm as the unit of measurement.
15, 3-1	FILTER/WATTS key	In the shifted mode, selects the filter time, in seconds, as the parameter to be displayed and/or adjusted; in the operating mode, selects W, mW, uW, or nW as the unit of measurement (determined by instrument ranging)
16, 3-1	ADRS/ZERO key	In the shifted mode, selects the IEEE-488 (GPIB) address as the parameter to be displayed and/or adjusted; in the operating mode, initiates the instrument zeroing routine.
17, 3-1	ENTER/SHIFT key	In the shifted mode, enters the displayed value of the selected parameter into the instrument and returns the instrument to the operating mode; in the operating mode, switches the instrument to the shifted mode.
18, 3-1	SENSOR connector	Provides means for connecting the power sensor to the instrument.
1, 3-2	Power receptacle	Provides means for connecting the AC power cord to the instrument.
2, 3-2	Fuse	Protects the power circuits against overload.
3, 3-2	Voltage selector switches	Switch the power circuits of the instrument to accommodate 100, 120, 220, or 240 volt AC power sources.
4, 3-2	GPIB connector (option)	Provides means for connecting the instrument to the IEEE-488 bus for remote operation.
5, 3-2	Recorder connector	Provides a DC voltage proportional to the measured values for use by an external recorder.

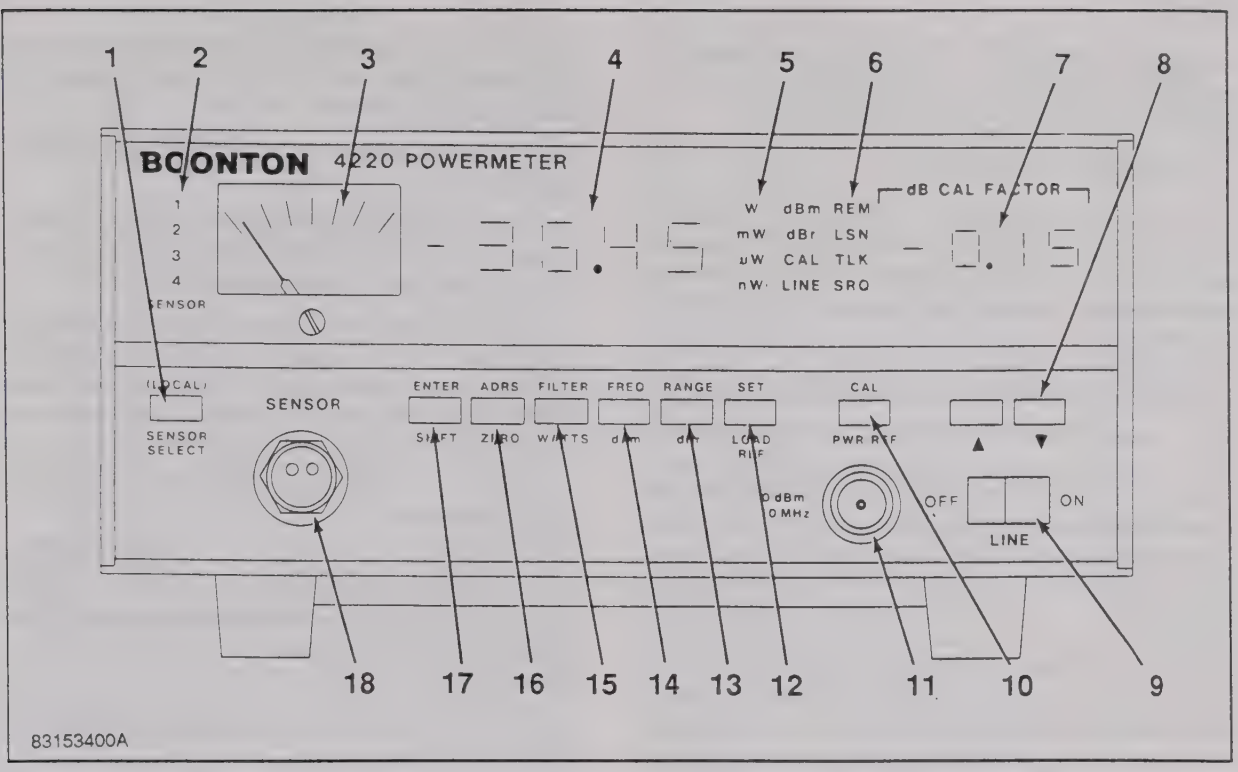

Figure 3-1. Model 4220, Front Panel Controls, Indicators, and Connectors.

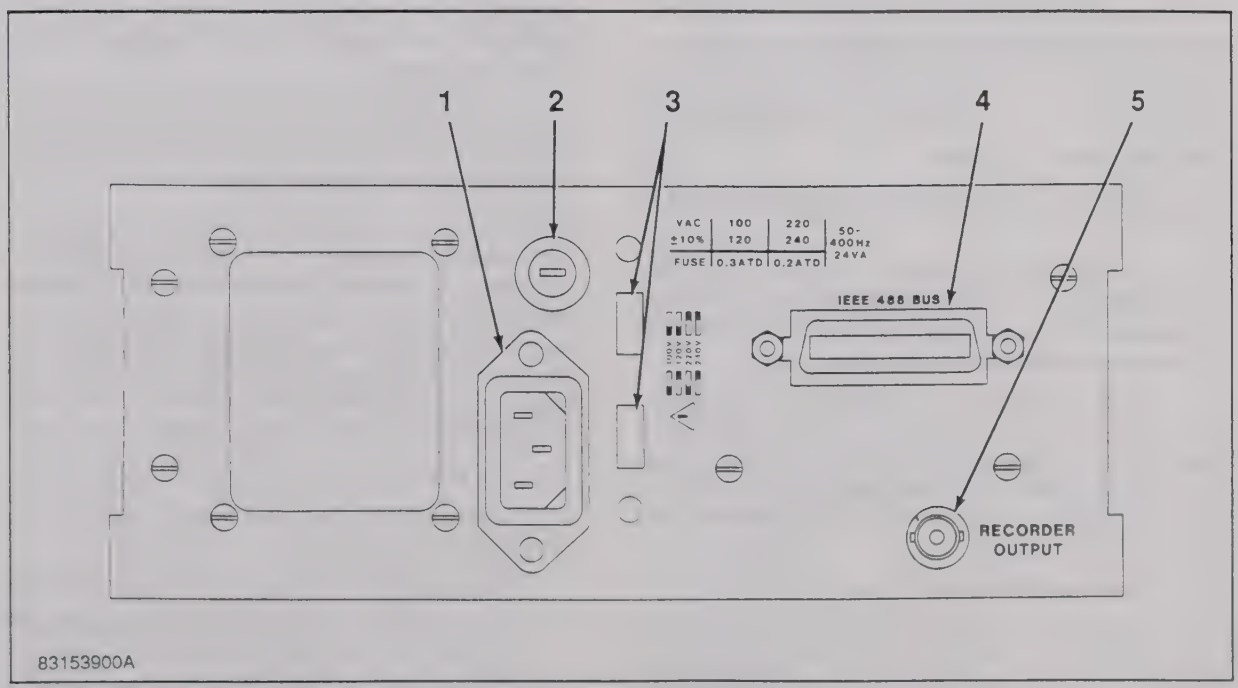

Figure 3-2. Model 4220, Rear Panel Controls and Connectors.

instrument will perform a short initialization routine, as described in paragraph 2-14. Operating parameters are set to default values, as described in paragraph 3-26.

3-7. SENSOR CONNECTION.

3-8. Select a sensor that covers the appropriate frequency and power ranges for the signal to be measured. Connect the sensor to the SENSOR connector using the five-foot cable supplied with the sensor, or with an accessory interconnecting cable.

3-9. MEASUREMENT PARAMETER SELECTION.

3-10. Sensor Selection. Calibration data for up to four sensors and up to 36 frequencies can be stored in non-volatile RAM in the instrument. If sensors are ordered with the instrument, the calibration data is entered into the instrument prior to shipment. Any calibrated sensor number can be selected using the (LOCAL)/SENSOR SELECT key. Pressing and holding the (LOCAL)/SENSOR SELECT key causes the sensor serial number and model to be displayed. With the instrument in the operating mode, toggle the displays using the (LOCAL)/SENSOR SELECT key until the desired serial number and model number of the sensor is displayed. Sensor calibration data must be present in the instrument before using a sensor. (Refer to paragraph 6-31.)

3-11. Range Selection. Any of seven measurement ranges, or autoranging, may be selected. If repetitive measurements are to be made over a narrow range of levels, selecting the appropriate instrument range may speed measurements. If measurements are to be made where the levels are unknown or vary widely, select the AUTO range. To select a range or autorange, proceed as follows:

a. Select the shifted mode by pressing the ENTER/SHIFT key.

b. Press the RANGE/dBr key. The dB CAL FACTOR display will show "rg" and the current instrument range. The main data display will show "AUTO" if in autoranging or the instrument range when the range is set.

c. If the displayed range is not the range to be used for the measurement, use the up/down keys to step through the ranges until the desired range is displayed. Nominal signal levels versus range are listed for each sensor in Table 6-5. Actual ranging points will vary according to sensor efficiency.

d. Press the ENTER/SHIFT key.

3-12. Frequency Selection. The frequency of the signal being measured must be entered in order to use stored high frequency cal factors. The instrument will then compute and apply the required correction factor to subsequent measurements. Frequency selection is not required if the sensor being used for the measurement is one for which high frequency cal factors are not stored in the instrument. High frequency cal factors for such sensors are entered manually as described in paragraph 3-15. To enter the signal frequency, proceed as follows:

a. With the instrument in the operating mode, press the ENTER/SHIFT key.

b. Press the FREQ/dBm key. The dB CAL FACTOR display will show "FrE" and the current frequency value will be displayed on the main data display.

c. If the displayed frequency value does not correspond to the frequency of the signal to be measured, adjust the frequency value using the up/down keys. Frequency limits are set by the sensor model (refer to Table 1-2). The up/down keys adjust the displayed value in 0.01 GHz increments.

d. When the correct frequency is displayed, press the ENTER/SHIFT key.

3-13. Filter Selection. Filtering may be adjusted to optimize measurement speed and display stability. Filter time, in seconds, can be adjusted in 0.05 second increments to a maximum of 20.00 seconds. To adjust the filter time, proceed as follows:

a. With the instrument in the operating mode, press the ENTER/SHIFT key.

b. Press the FILTER/WATTS key. The dB CAL FACTOR display will show "FIL", and the current filter time or the word "Auto" indicating default filter values will be shown on the main data display. (Refer to paragraph 4-19 for default filter values.)

c. If the filter time is to be changed, use the up/down keys to bring the displayed filter time to the desired value.

d. Press the ENTER/SHIFT key.

3-14. Reference Level Selection. If dBr measurements are to be made, a reference level must be entered into the instrument. The entered reference level will be subtracted automatically from subsequent measurements in the dBr mode. Reference level may be entered in either of two ways: any reference value from -99.99 dBm to +99.99dBm may be entered, or the current measurement value may be entered as the reference level. The procedures are described below.

a. To enter a reference level using the first method:

(1) With the instrument in the operating mode, press the ENTER/SHIFT key.

(2) Press the SET/LOAD REF key. The dB CAL FACTOR display will show "SEt" and the main data display will show the current reference level.

(3) If the displayed reference level requires adjustment, use the up/down keys to adjust the displayed value until the desired reference level is displayed.

(4) Press the ENTER/SHIFT key.

b. To use the current measurement value as the reference level, press the SET/LOAD REF key while the instrument is in the operating mode. The currently displayed level will be used by the instrument as the reference level for subsequent dBr measurements.

NOTE

The stored reference level will remain unchanged until a new reference level is entered or the instrument is turned off.

3-15. dB Calibration Factor Entry. The dB CAL FACTOR display shows the current sensor high frequency cal factor. Measured levels are automatically corrected in accordance with this calibration factor to compensate for sensor characteristics. The sensor calibration factor can be entered in either of two ways, as follows:

a. The calibration factor is computed automatically by the instrument based on the sensor and frequency selection. (Refer to paragraph 3-12 for frequency selection.)

b. The cal factor may be entered manually from the calibration sheet supplied with the sensor. Adjust the dB CAL FACTOR display using the up/down keys to select the required value. The up/down keys adjust the calibration factor in 0.01 dB steps over a range of -3.00 dB to +3.00 dB. Cal factors entered in this manner will be used by the instrument for subsequent measurements, but will not be stored in non-volatile RAM.

c. Entering a dB cal factor forces the operating frequency to its default value.

3-16. Bus Address Selection (IEEE-488 Option Only). On instruments equipped with the IEEE-488 option, the assigned instrument bus address must be entered if the instrument is to be operated remotely over the bus. The procedure is as follows:

a. With the instrument in the operating mode, press the ENTER/SHIFT key.

b. Press the ADRS/ZERO key. The dB CAL FACTOR display will show "Adr" and the main data display will show the current instrument bus address.

c. Use the up/down keys to change the displayed instrument bus address to the desired number.

d. Press the ENTER/SHIFT key.

e. The new address will be stored in non-volatile memory until changed.

3-17. ZEROING THE INSTRUMENT.

3-18. Zeroing should be performed when the instrument is energized, a sensor has been changed, or the instrument has drifted a significant amount with respect to the signal level being measured. For large signals (measurements taken on range 4, 5 or 6), this may be done once every several hours. For very small signals (measurements taken on range 0, 1, 2, or 3), zeroing should be done before each measurement. When zeroing is performed, the instrument calculates and stores zero corrections for each range, and applies the corrections to subsequent measurements. To zero the instrument, proceed as follows:

a. Ensure that the power sensor is not connected to any power source and that the reading is stable.

b. With the instrument in the operating mode, press the ADRS/ZERO key. Brackets will be shown on both displays during the zeroing routine, and the sensor and instrument should not be disturbed until zeroing has been completed. The displays then revert to normal operation.

3-19. CALIBRATING THE INSTRUMENT.

3-20. The built-in 50 MHz calibrator provides a convenient means for calibrating the instrument. Calibration can be performed any time to assure accuracy. To calibrate the instrument, proceed as follows:

a. Connect the sensor to the 0 dBm 50 MHz connector on the front panel of the instrument.

b. With the instrument in the operating mode, if the CAL annunciator is not lighted, press the CAL/PWR REF key. The CAL annunciator will light to indicate that the 50 MHz calibrator is on. If the calibrator was off, wait 15 minutes for the calibrator to stabilize.

c. Press the FREQ/dBm key. The dBm annunciator will light.

d. Press the ENTER/SHIFT key to select shifted operation.

e. Press the CAL/PWR REF key. The main data display will show "rEF" and the dB CAL FACTOR display will show "CAL".

f. Press the ENTER/SHIFT key. The instrument will execute the calibration routine.

g. When calibration has been completed, the main data display will show 0.00 dBm (+/- any cal factor).

NOTE

If the 50 MHz calibrator is off when the calibration routine is attempted, an error message will be displayed.

h. Press the CAL/PWR REF switch to toggle the 50 MHz calibrator off (if required).

i. Disconnect the sensor from the 0 dBm 50 MHz calibrator connector.

3-21. MAKING A MEASUREMENT.

3-22. To make a measurement, proceed as follows:

a. Energize the instrument and allow a 15 minute warm up.

b. Ensure that the proper sensor is connected to the SENSOR connector. (Refer to paragraph 3-10 for sensor selection.)

c. Ensure that the required measurement parameters have been entered in accordance with paragraphs 3-9 through 3-15, as applicable.

d. Zero the instrument per paragraph 3-17.

e. Calibrate the sensor per paragraph 3-19.

f. Ensure that the instrument is in the operating mode by pressing the FILTER/WATTS, RANGE/dBr, or FREQ/dBm key.

g. Connect the sensor to the signal source to be measured.

h. Read the numerical value of the measured level on the main data display and the unit of measurement from the lighted main data display annunciator.

3-23. GPIB OPERATION.

3-24. If the instrument is equipped with the IEEE-488 option, it can be operated remotely over the bus. Refer to Section IV for details of such operation.

3-25. INITIALIZING THE INSTRUMENT.

3-26. At any time, the instrument can be initialized to all default values by setting the LINE switch to OFF, then back to ON. This will restore all parameter variables to their default values, as follows:

Parameter Variable	Default Value
Mode	Operating
Sensor	No. 1
Measurement Unit	Watts
dB CAL FACTOR	0.00 dB
Frequency	0.00 GHz
Filter	Auto
Range	Auto
dBr Reference	0.00 dBm
Calibrator	On
Internal Zeroing	Cleared
Internal Reference Calibration	Cleared

SECTION IV
APPLICATION NOTES

4-1. INTRODUCTION.

4-2. This section provides detailed background information on various aspects of operation of the Model 4220. It is assumed that the reader is familiar with the basic operating procedures covered in Section III. This section covers the following topics:

a. Sensor calibration

b. Zeroing

c. Filtering

d. Noise

e. Dynamic range

f. Measurement time

g. High frequency accuracy

h. Chart recorder operation

i. Waveform sensitivity

j. GPIB operation (option)

4-3. SENSOR CALIBRATION.

4-4. General. Two types of calibration are associated with the Model 4220 - instrument calibration and sensor calibration. The instrument (less sensors) must be calibrated using a DC source to ensure interchangeability of sensors. Instrument calibration procedures are covered in Section VI. Sensor calibration data is of two types: linearity and high frequency calibration factors. Sensor calibration data for up to four sensors can be stored in non-volatile RAM.

4-5. 14-Point Linearity Data. Linearity data, also referred to as AC reference frequency linearity data, is supplied with the sensor and can be manually entered into non-volatile RAM. For sensors ordered with the instrument, linearity data is installed before the instrument is shipped.

4-6. At the reference frequency (50 MHz, or 22, 33, 40, 60, or 94 GHz), each sensor has two gain factors for each range: upscale and downscale points. Refer to Figure 4-1. The upscale points are in the range of 5000, which is a gain correction factor. Upscale points are calibrated at the factory at about 70% of full scale. The downscale number is a second order type of correction at about 25% of full scale. Thus, for a diode sensor (7 ranges), there are 14 points; for thermal sensors there are eight points. Ranges 0 and 1 share the same data points.

4-7. High Frequency Calibration Points. In addition to linearity data, there are high frequency calibration points as shown in Figure 4-2. Calibration points covering the entire sensor frequency range are supplied with each sensor. Below 1 GHz, the sensor response is flat, and frequency calibration points need not be entered.

4-8. Figure 4-2 shows data for 17 points; however, space for up to 36 points for each of four sensors is provided in non-volatile RAM. Frequency calibration points need not be in equal frequency increments; however, the entry of data must be done in ascending order of frequency. Generally, for both diode and thermal sensors, a calibration factor of 0 dB is entered at 0.00 GHz so that the instrument may be operated below the first data point. During measurement, frequency calibration points are linearly interpolated and, if a measurement frequency is entered that is outside the range of the sensor selected for the measurement, an error message is displayed.

4-9. ZEROING.

4-10. The automatic zeroing routine of the instrument takes measurements on the lowest five ranges and applies these as correction factors on subsequent measurements. Offsets in the sensor and input amplifiers are linearly corrected in the internal software. Offsets on the highest ranges are below 0.02% of full scale, and do not need correction.

4-11. Input power to the sensor must be removed before the zeroing function is executed or an error message will be displayed. The instrument will perform zeroing, however, if the signal is less than full scale on range 0. This feature provides a great deal of offset capability for temperature effects without rezeroing the input amplifier hardware.

4-12. For full accuracy at low signal levels, power must be removed from the sensor several seconds before zeroing to allow the sensor to settle. This is especially true if a large signal had been applied to the sensor in the previous 20 seconds or so because of the dielectric absorption of the capacitors in diode sensors, and because of thermal retention in thermal sensors. The error resulting from different input conditions can be determined from Figure 4-3 or 4-4, as applicable. The curves in these figures show the decay of measured power after a large signal has been applied. The typical error that can be expected by zeroing too quickly after application of a large signal is equal to the offset power at the time of zeroing.

4-13. The Model 4220 initiates zeroing immediately when the ZERO key is pressed. The user must delay zeroing according to system requirements when the sensors are used over a wide dynamic range. For example, if it is determined from the application that five seconds are required from

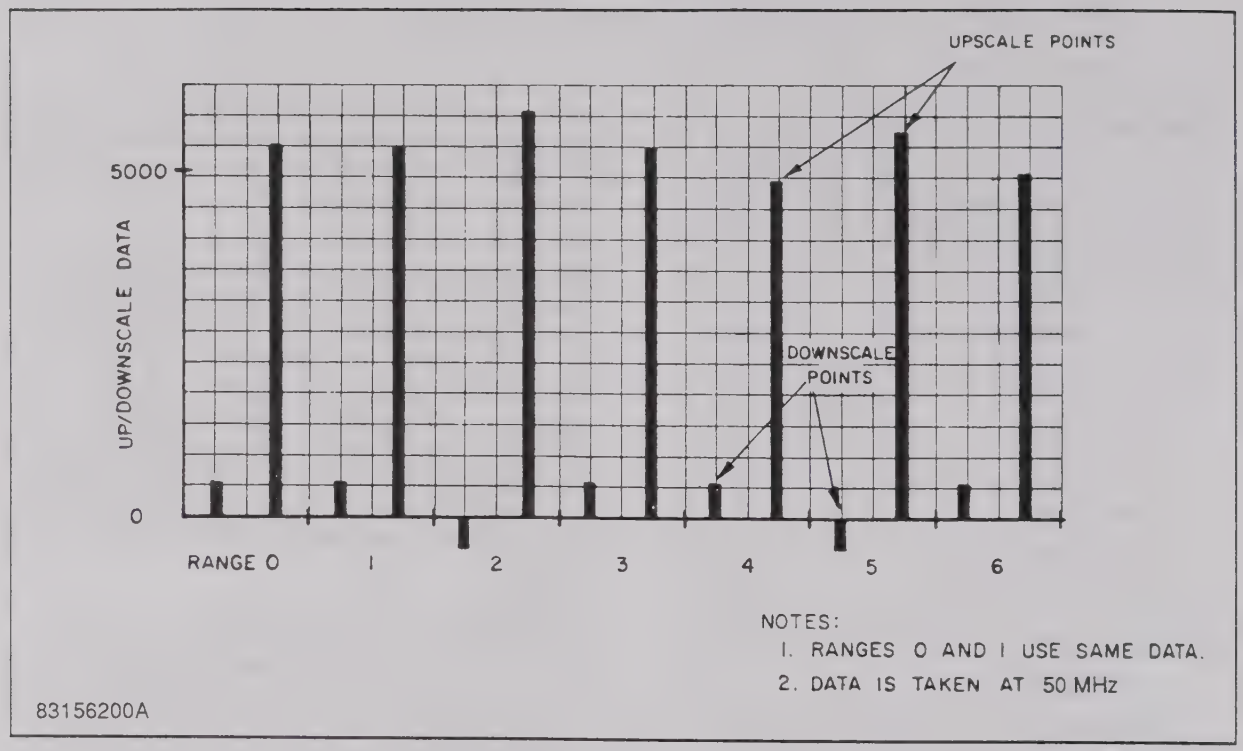

Figure 4-1. 14-Point Sensor Calibration.

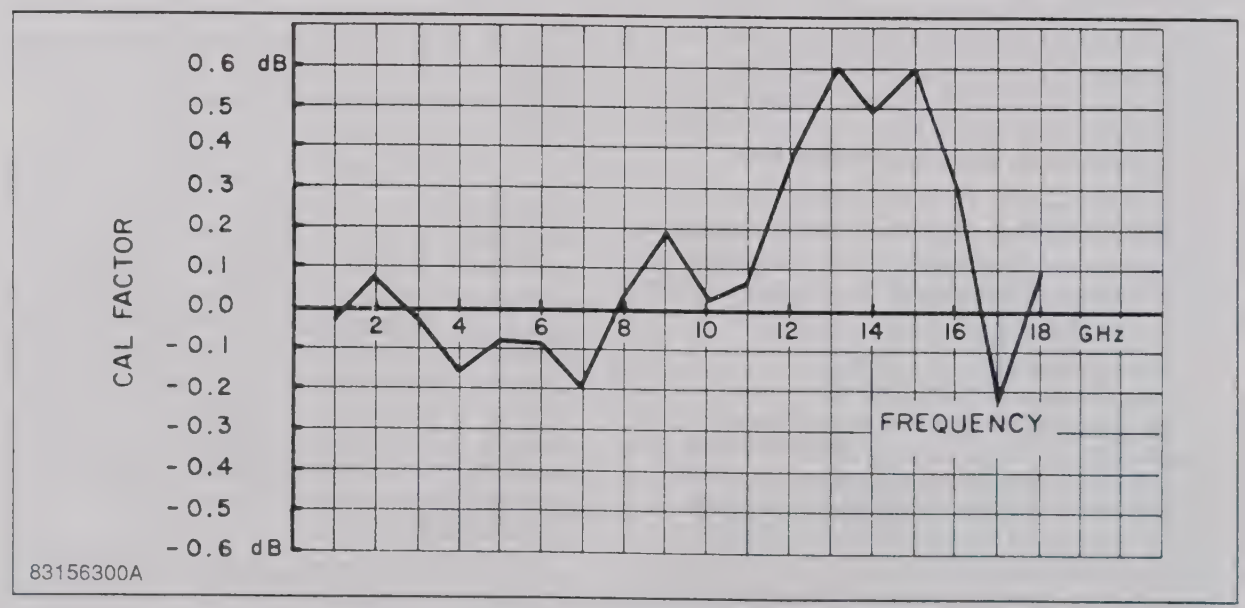

Figure 4-2. Typical High Frequency Sensor Calibration.

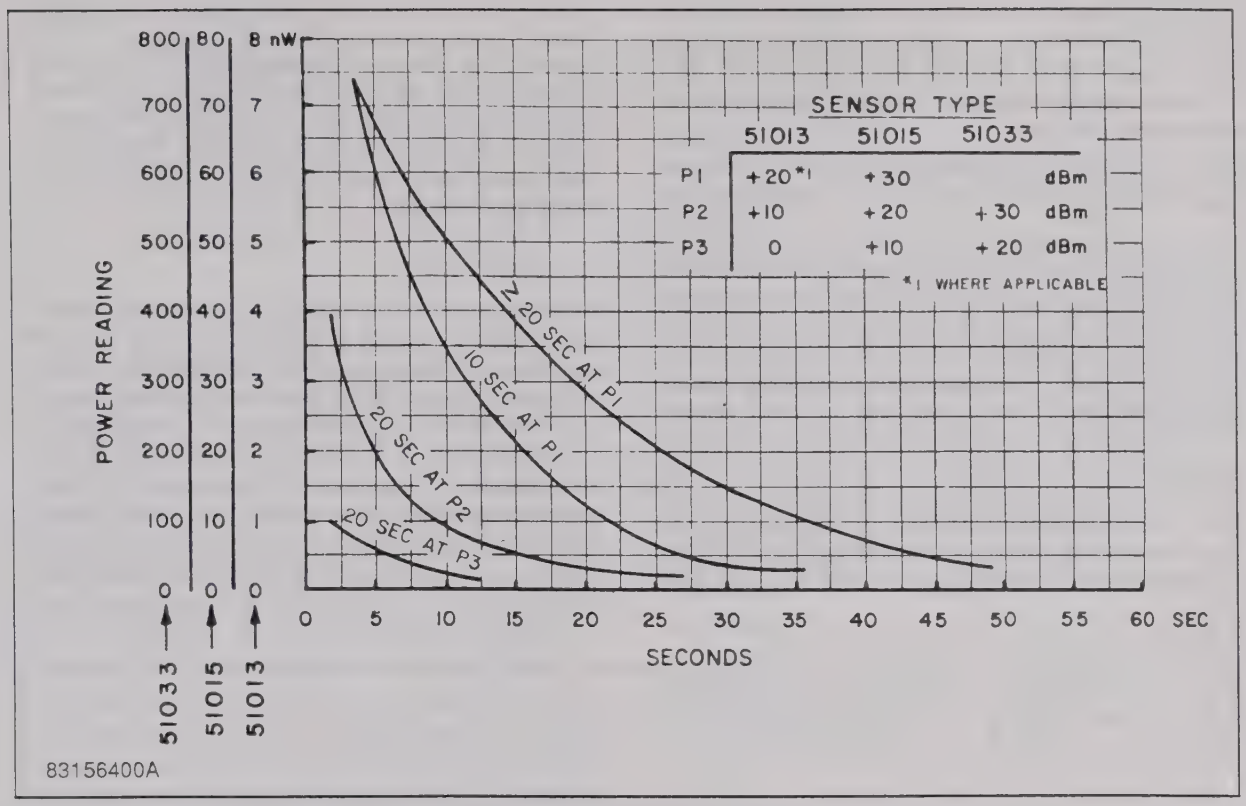

Figure 4-3. Diode Sensor Decay.

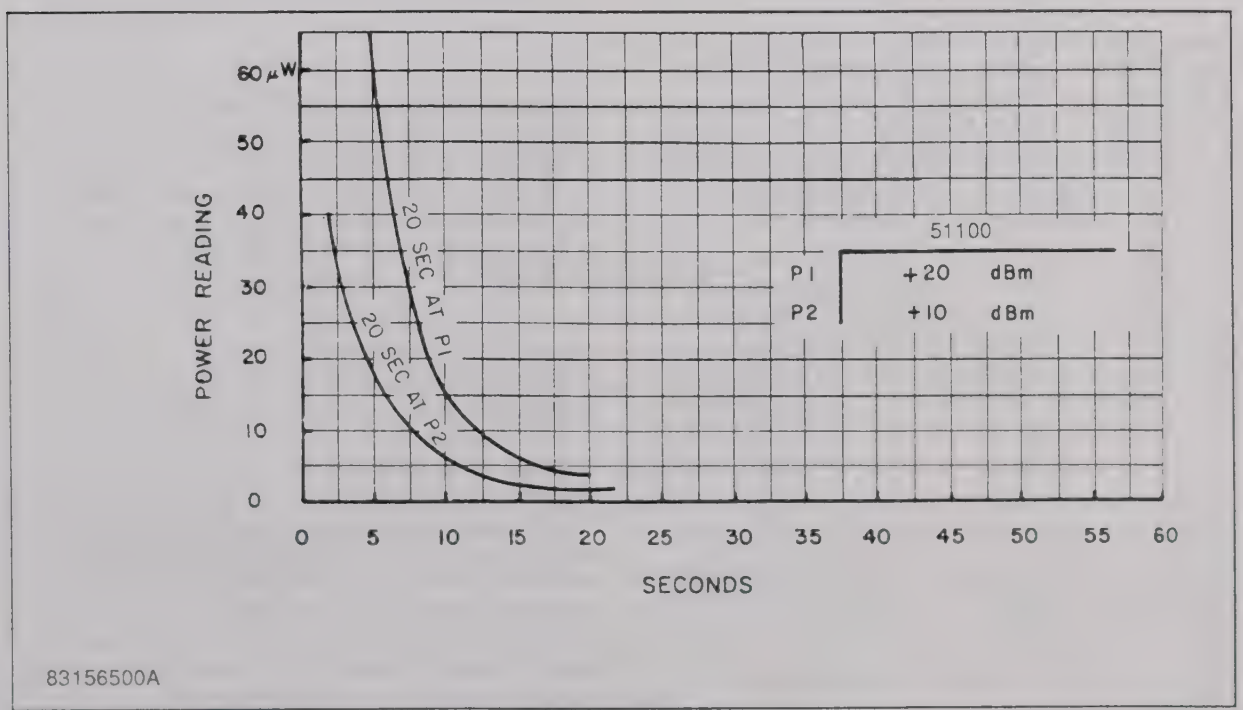

Figure 4-4. Thermal Sensor Decay.

power off to the zeroing operation, then the user should wait five seconds after removing power from the sensor before pressing the ZERO key.

4-14. The zeroing time on each range has been optimized for speed and accuracy. Total zeroing time is 5 seconds.

4-15. Zeroing should be done when the instrument is energized, the sensor has been changed, or the instrument has drifted a significant amount with respect to the signal being measured. For large signals (range 4, 5, or 6), this may be once every several hours, if at all. For very small signals (range 0, 1, 2, or 3), it is recommended that zeroing be done immediately before each measurement.

4-16. DYNAMIC RANGE.

4-17. The hold range mode is useful when it is known that the signal will vary over a certain limited range. (The hold range mode is active when a specific instrument range, other than autorange, has been selected.) In the hold range mode, the decimal point and units will remain fixed. The dynamic range of this mode is limited by the zero offset and the resolution, as shown in Figure 4-5. It can be seen from this figure that the useful dynamic range is 20 dB if the error is to be kept below 0.1 dB.

4-18. FILTERING.

4-19. The Model 4220 employs digital filtering (averaging of measurements) to reduce the noise floor of the instrument and to stabilize measurements. Selectable averaging of up to 400 samples is provided, at an input channel sampling rate of 50 milliseconds, which corresponds to a maximum filter time of 20 seconds. The minimum filtering is one sample or 50 milliseconds. Alternately, the instrument can be programmed to use default filter lengths which are a function of range. The default values are optimized for speed and low noise under general conditions. Default values are as follows:

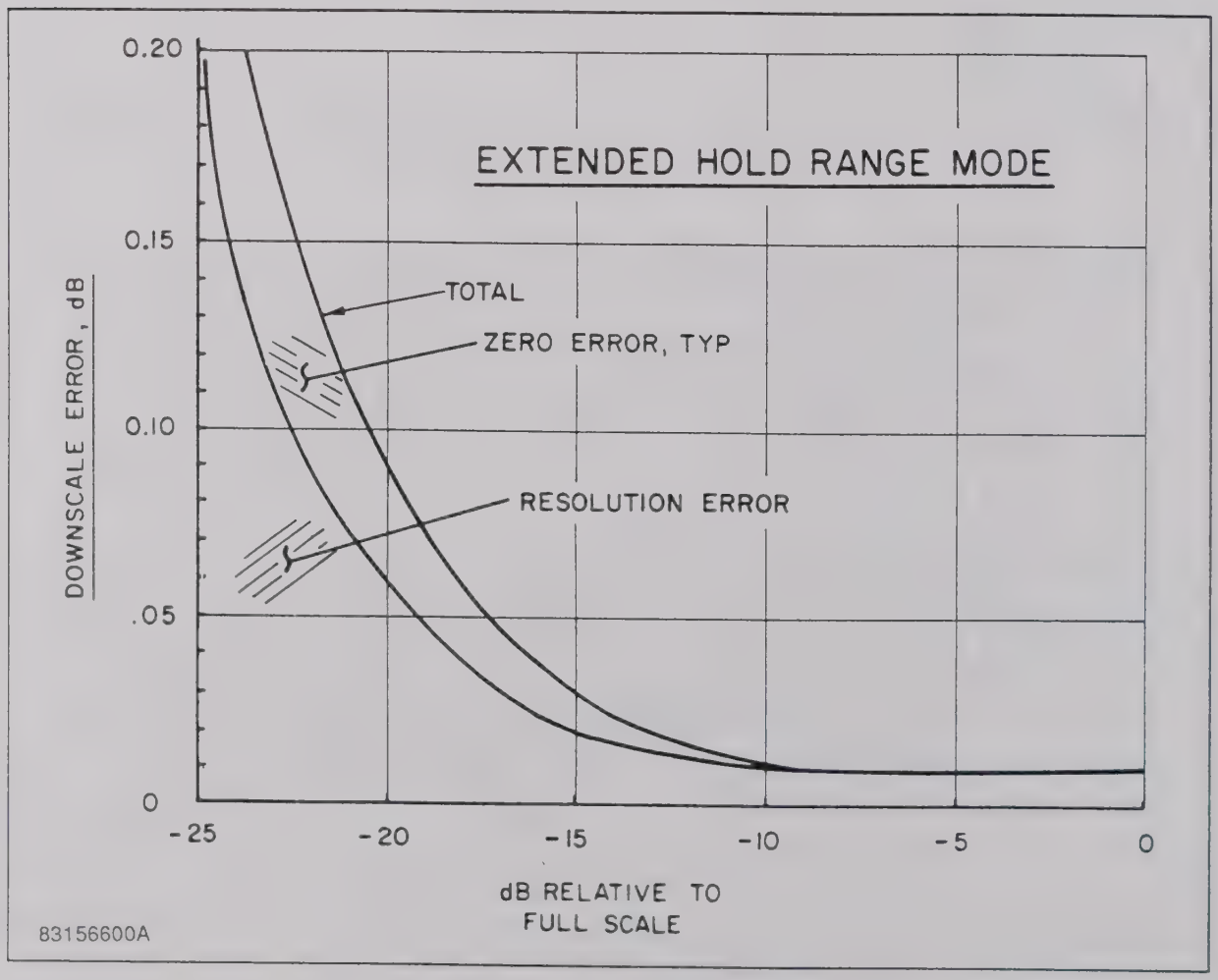

Figure 4-5. Extended Hold Range Mode.

Range	Filter Default Value
0	2.8 seconds
1	0.8 second
2	0.8 second
3	0.8 second
4	0.8 second
5	0.8 second
6	0.8 second

4-20. The filtering technique used is digital pipeline filtering, also referred to as circular filtering or moving average filtering. The displayed measurement is simply an equally weighted average of the last x seconds worth of samples, where x is the filter length in seconds. For purposes of noise and settling time, the number of samples is not important, but the time is important. For example, if a three second filter is used, the noise is the same whether 60 or 600 samples are taken in that interval, provided that the samples are taken above a certain rate. For this reason, filter selection in the Model 4220 is done on the basis of seconds, rather than the number of samples.

4-21. The bottom end sensitivity of the instrument is limited by sensor noise. An RMS noise specification is valid since the sensor noise and the amplifier noise are band-limited and Gaussian. The noise level, specified in picowatts at a certain filter length, is sufficient to calculate the error due to noise at any signal level, for any filter, as shown in the discussion of noise that follows.

4-22. NOISE.

4-23. Noise Reduction. The amount of noise reduction that can be realized has no theoretical limitation, except that drift enters into the picture at filter lengths over 20 seconds. The digital filter has a bandwidth and rolloff curve just as any filter does; the bandwidth can be reduced arbitrarily. The effective noise bandwidth is 0.469/t, where t is the filter length. For example, with a filter length of 4 seconds, the equivalent noise bandwidth is 0.12 Hz.

4-24. Figure 4-6 is a nomograph showing the noise reduction that applies for various filter lengths, given the sensor noise with 2.8 second filtering. (This is the time for which diode sensor noise is specified.) Noise power is inversely proportional to the square root of the filter length. Normally, noise power varies directly with filter bandwidth; however, because power sensors are square-law devices (detected voltage is proportional to power), the noise power is proportional to the square root of the bandwidth. This can be demonstrated with noise measurements. At very low filter lengths (less than 150 milliseconds), however, the noise does not increase without bound for all sensors because the input amplifier noise is restricted with hardware filters to a few Hertz. This additional filtering is not shown in the nomograph.

4-25. Error Computation. Since the noise is Gaussian, both before and after filtering, statistics show the level of confidence factor that can be associated with a given reading. (At medium and high power levels, the confidence factor is essentially unity.) Figure 4-7 shows a typical set of samples and a typical error band specification of 2 sigma. Under these conditions, 95.4% of the readings will fall within ± 2 sigma.

4-26. Figure 4-8 shows the confidence factor for other error bands. The error band is expressed in pW, regardless of the power level. (The percentage error band can also be calculated as shown below.) The RMS noise is taken from the sensor specifications and modifies as necessary for filter lengths other than 2.8 seconds. Knowing any two of the three parameters (error band, RMS noise, and confidence factor), the third can be computed. For example, if the sensor RMS noise is 65 pW and the confidence factor is to be 95.4%, the error band is 130 pW, single sided (± 130 pW). If this were the case, at a measurement level of 1300 pW the percent error band would be 10%, corresponding to about ± 0.44 dB.

4-27. Noise Error Examples. Figures 4-9 and 4-10 show the computed error for the 51013 diode sensor at different power levels, for 2.8 and 10 second filters. To attain these results, the sensor must be at a stable temperature, and zeroing must be done immediately before the measurement is taken.

4-28. Integration of Power. With long filtering, instrument readings may seem erroneous because the filter has not been cleared. For example, with a 20 second filter, if a 2 second RF pulse is applied, the instrument display will indicate a nonzero level for 18 seconds after the pulse has terminated. Additional pulses will be integrated along with the first until, by the process of selective deletion, the pulses are removed one at a time from the filter. Actually, measurement samples are deleted, not the pulses, giving rise to a ramping effect at the instrument display/output. This is shown in Figure 4-11. In all senses, the filter is a simple integrator.

4-29. Clearing of Filter. When long filter times are used, it may become troublesome at times to wait for the filter to clear. If the Auto filter function is selected, the filter is cleared after power changes by 0.02 dB, and filtering then resumes. Clearing can also be accomplished by changing the filter length to any different value and then resetting it using the GPIB bus; however, with bus operation, most of the trigger modes clear the filter at trigger time.

4-30. Partial Results. Measurement time is affected by the filter since valid readings to within a certain error band can be obtained only when the filter is full. If the filter has been cleared, data is available at reduced accuracy immediately after the first 50 millisecond sample. The filter uses the number of samples as a divisor when computing the average, and the output/display does not ramp but homes in on the result instead as the samples accumulate.

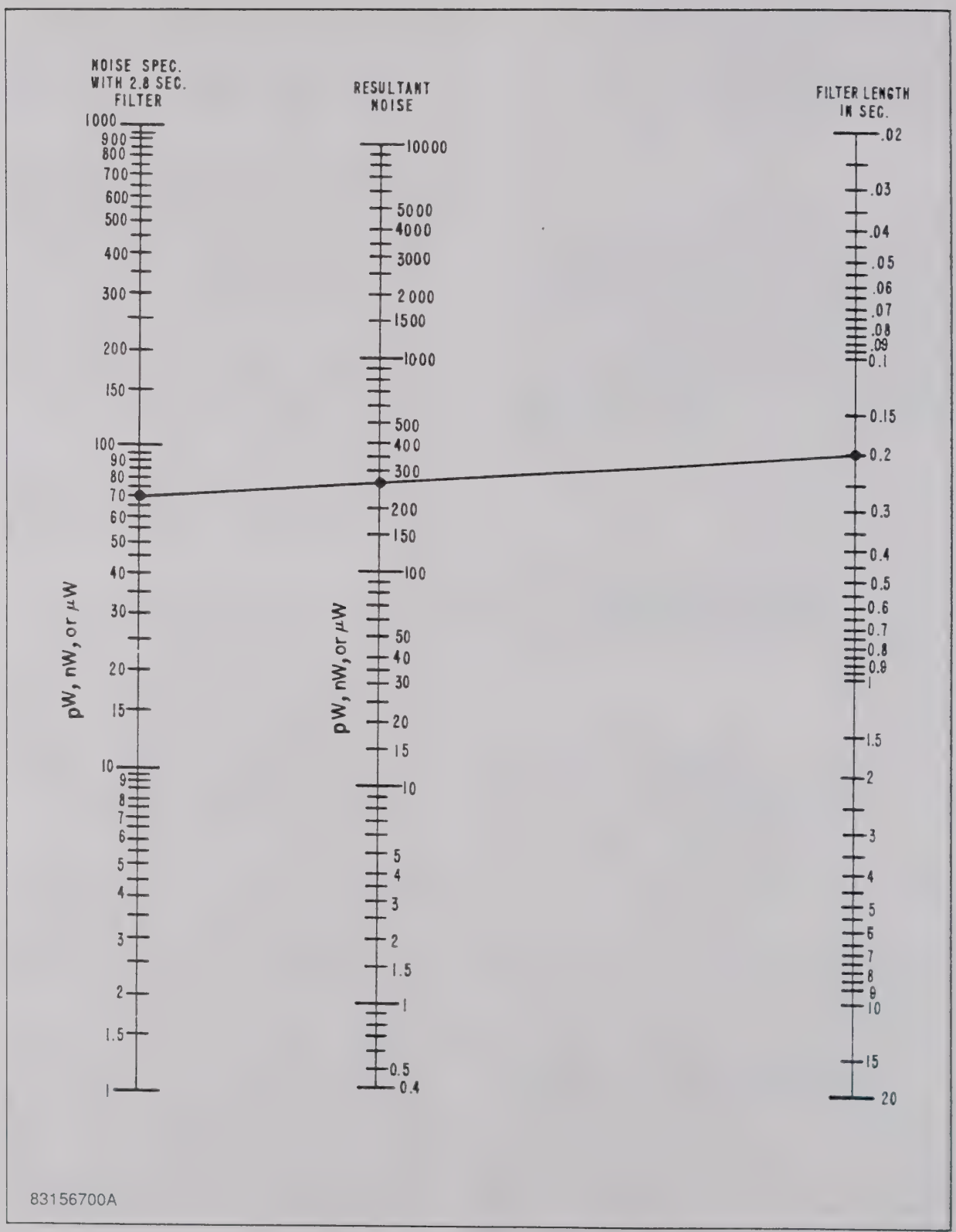

Figure 4-6. Noise Reduction.

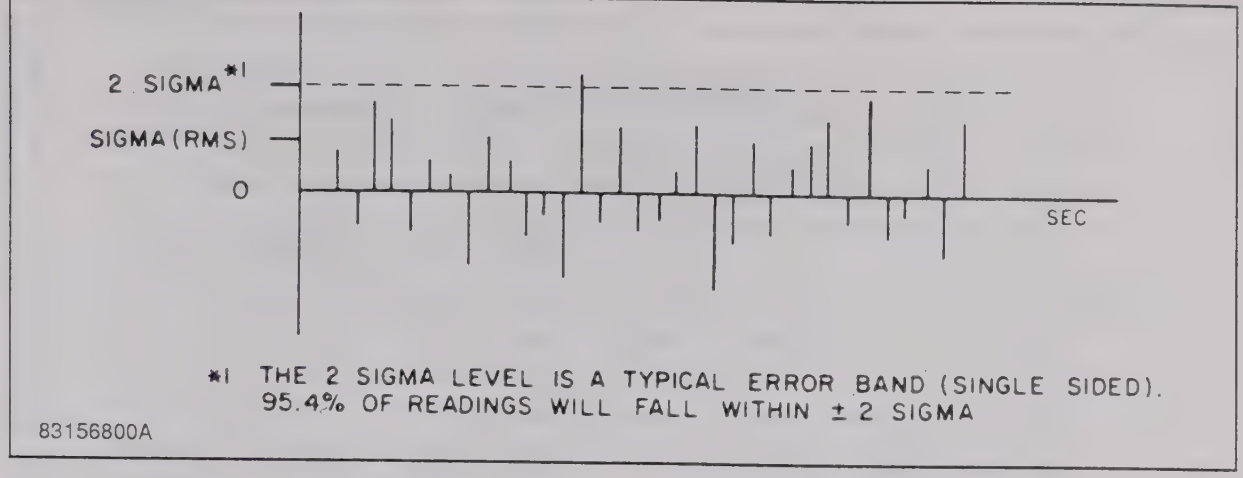
2 SIGMA*1
SIGMA (RMS)
0
SEC
*1 THE 2 SIGMA LEVEL IS A TYPICAL ERROR BAND (SINGLE SIDED). 95.4% OF READINGS WILL FALL WITHIN ± 2 SIGMA
83156800A

Figure 4-7. Typical Error Band Specifications.

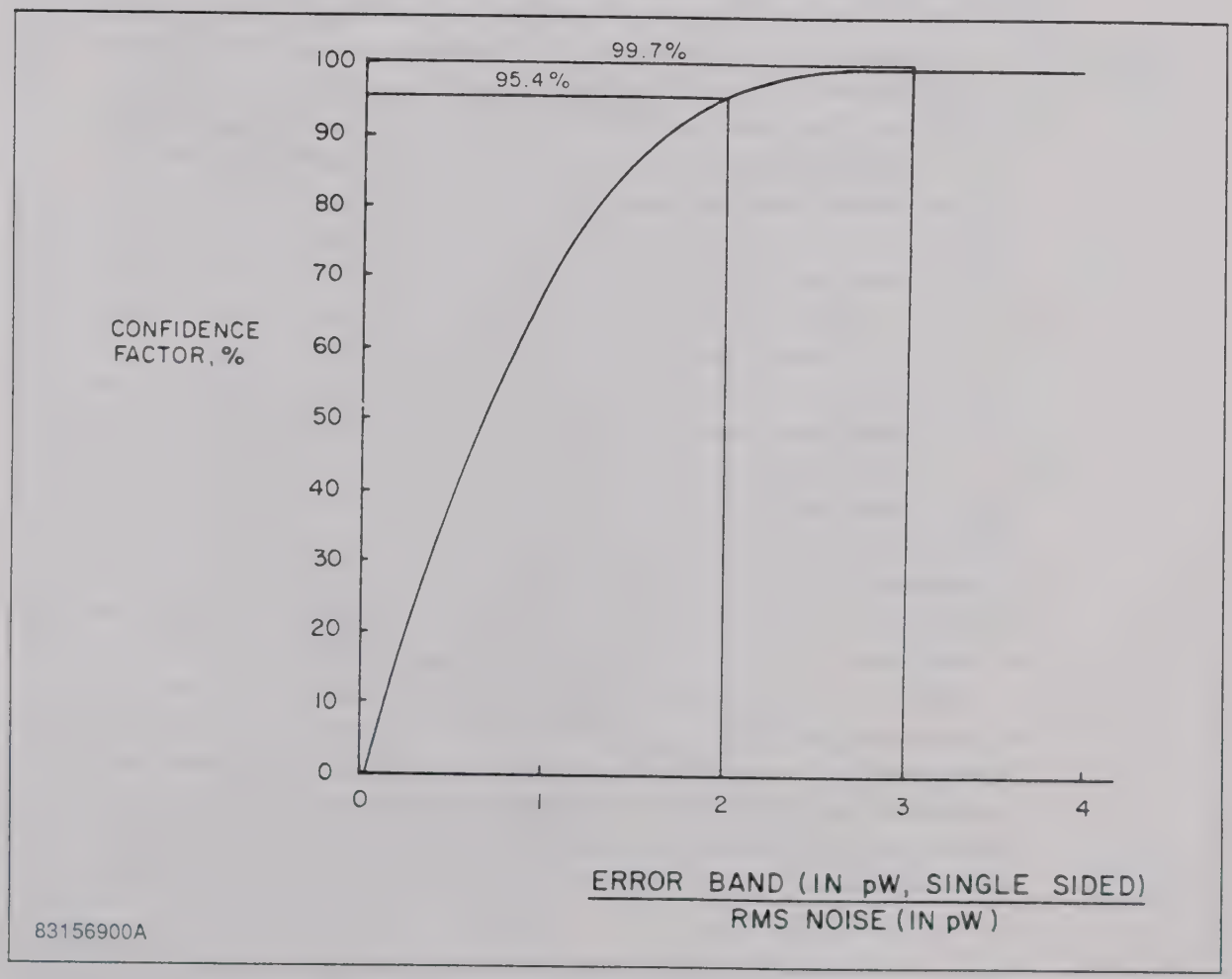

Figure 4-8. Probability of Falling within an Error Band.

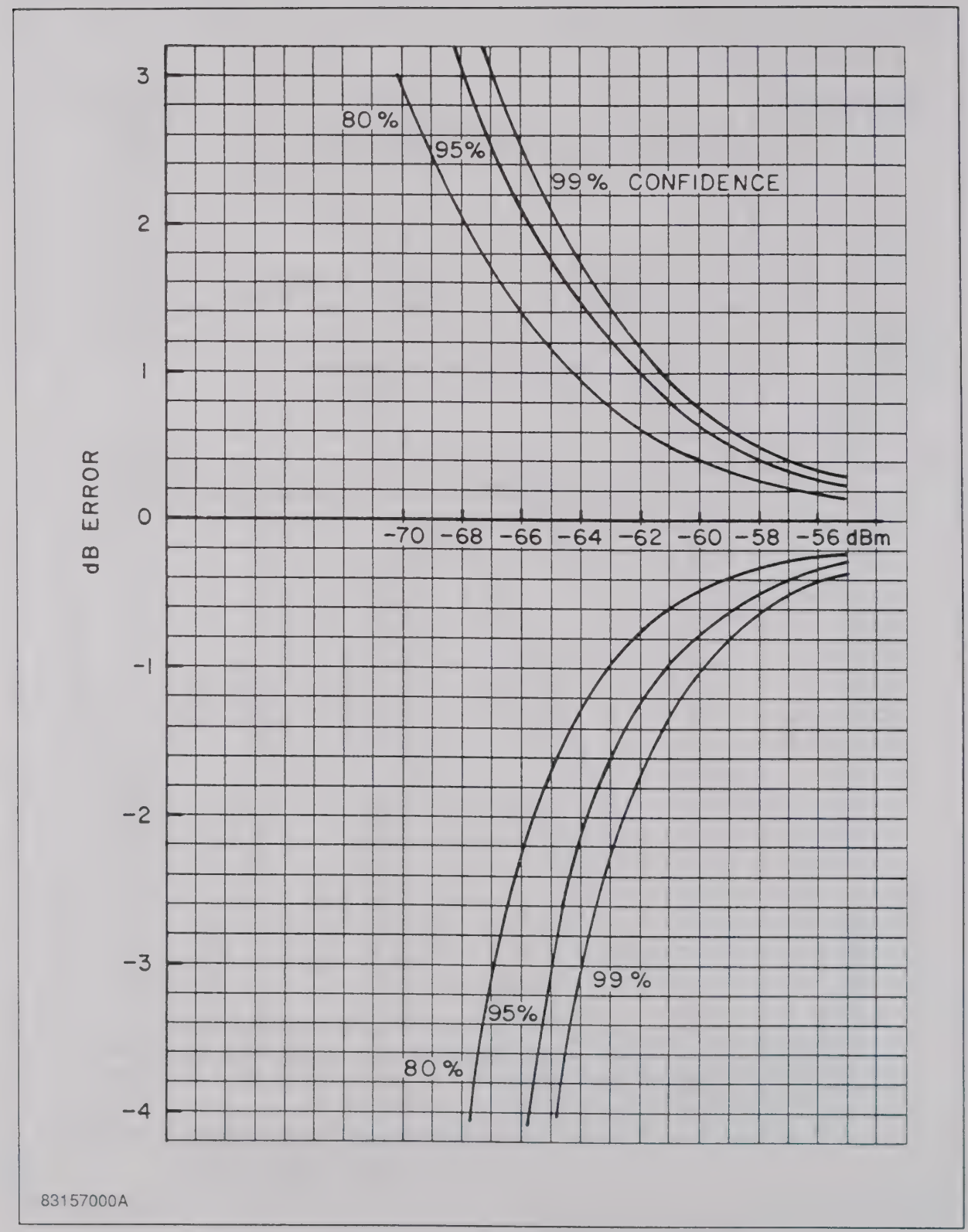

Figure 4-9. Confidence Curves, 51013 Sensor with 2.8 Second Filter.

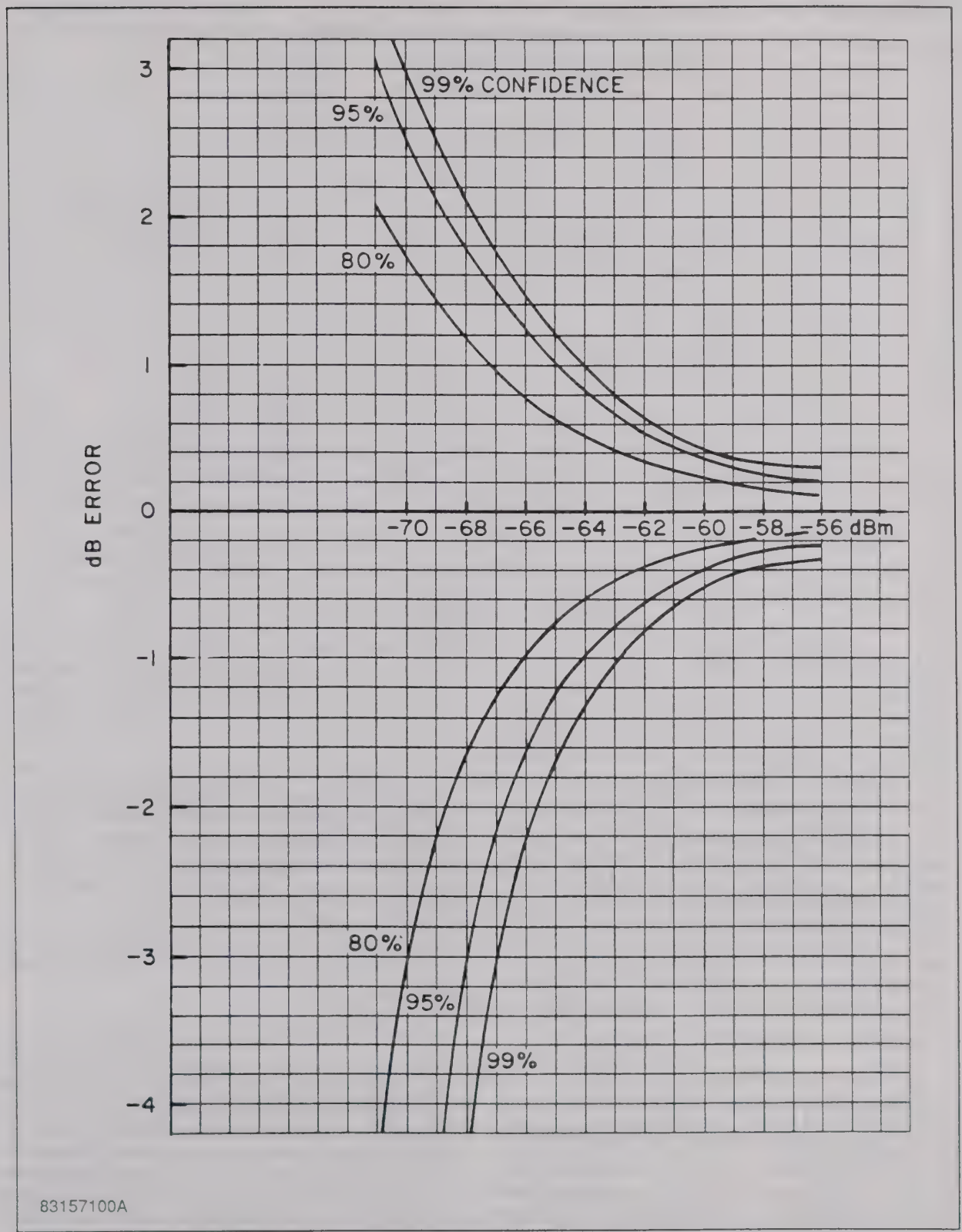

Figure 4-10. Confidence Curves, 51013 Sensor with 10 Second Filter.

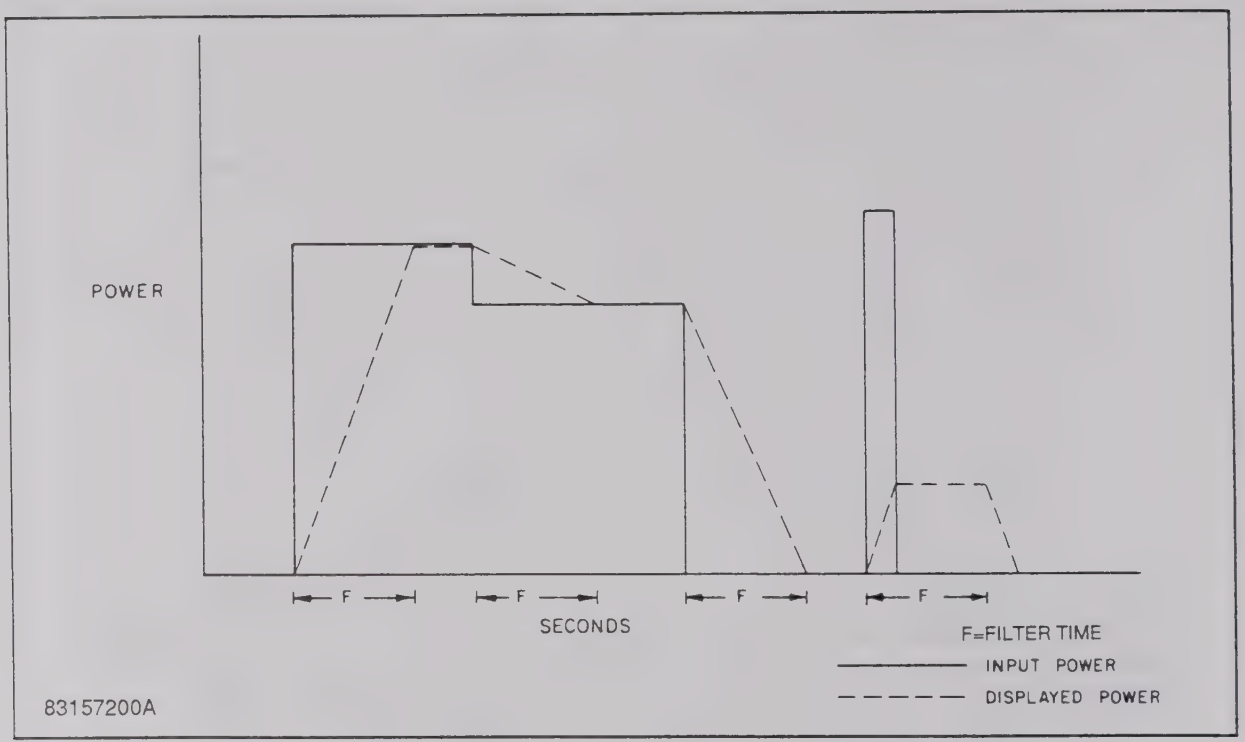

Figure 4-11. Integration of Power.

4-31. MEASUREMENT TIME.

4-32. Step Response. The measurement time from a power input step is the sum of the overhead time and the length of the digital filter, where the overhead time is defined as the time delay due to sensor response time and measurement software (processing). The overhead time is given in paragraph 4-34 for certain conditions.

4-33. Continuous Response. Regardless of the overhead time or the digital filter length, the Model 4220 will output readings at a rate of about 50 milliseconds with the display operating. As the sensor and the digital filter settle, readings will ramp up or down at that rate.

4-34. Overhead Time. Overhead time is <350 milliseconds for diode sensors and <450 milliseconds for thermal sensors under the following conditions:

a. Settling to 99% or 0.04 dB of final power

b. Power step of 10 dB

c. Range does not change

d. Digital filter set to minimum (50 milliseconds, which is a sample of one).

4-35. The power step may be upward or downward. Smaller power steps will decrease this time slightly; larger power steps in the downward direction will increase the time significantly. A 40 dB downward step, for example, will take several seconds to settle to 0.04 dB.

4-36. Digital Filter. The digital filter is a moving average or pipeline filter which simply integrates the readings over the last x seconds, where x is the filter length. A step input to the filter will produce a linear ramp at the output, terminating when the filter is full.

4-37. Default Filter Lengths. Although any filter length from 50 milliseconds to 20 seconds may be chosen, default filter lengths are programmed into the instrument for optimum general conditions. (Refer to paragraph 4-19.) For diode sensors, the range break-points are roughly in 10 dB steps, with the range 0 to 1 break-points at approximately -54 dBm.

4-38. Settled Measurement Time. In the free run settled mode, output data updates are held off until the measurements have settled.

4-39. HIGH FREQUENCY ACCURACY.

4-40. Power measurements, particularly at high frequencies, have a number of uncertainties which generally arise from imperfect SWRs. If all power sources and power meters had impedances that were resistive and equal to Z_o (the characteristic impedance of the measuring system), most problems would disappear. The incident, dissipated, and maximum available powers would all be equal, and the indicated power would differ only by the inefficiency of the power sensor in converting all dissipated power to indicated power. Tuning eliminates most of the SWR effects, but is cumbersome and

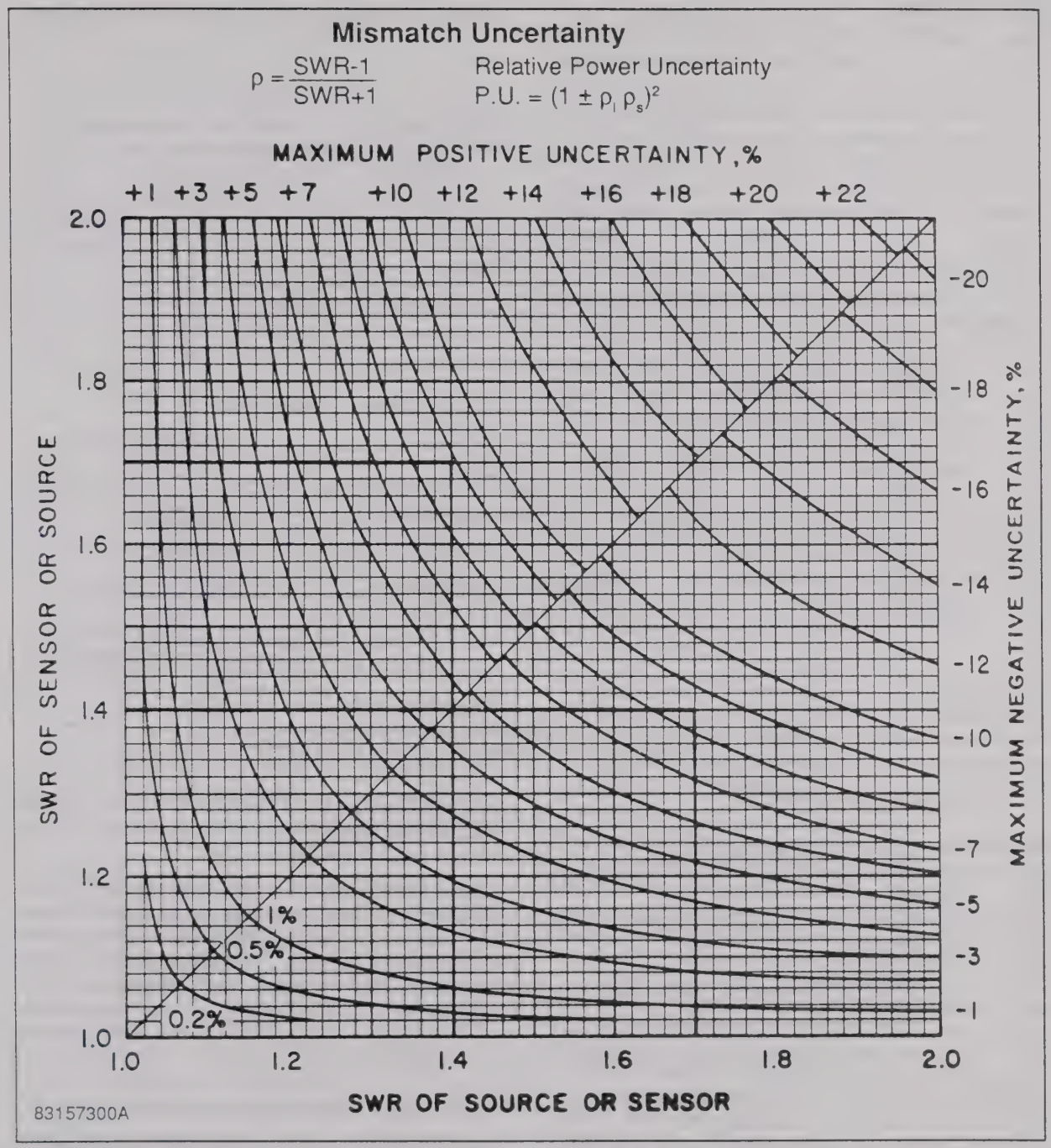

Figure 4-12. Mistmatch Uncertainties Chart.

is therefore seldom done. The use of attenuator pads can mask imperfect SWRs, as can the use of a directional coupler to level the source and reduce its reflection coefficient to a value equal to the directivity factor of the directional coupler. Boonton 51015 and 51033 power sensors have precision, built-in attenuators which improve the SWR over that of other power sensors.

4-41. When the complex coefficients of both an imperfect source and a power sensor are not known, but the maximum actual SWRs of both are known, the maximum positive and negative uncertainties of the measured power, Pm, can be determined from Figure 4-12. For example, if the SWR of the source is known to be 1.2 and the SWR of the power sensor is 1.25, the uncertainty derived from Figure 4-12 is 2%.

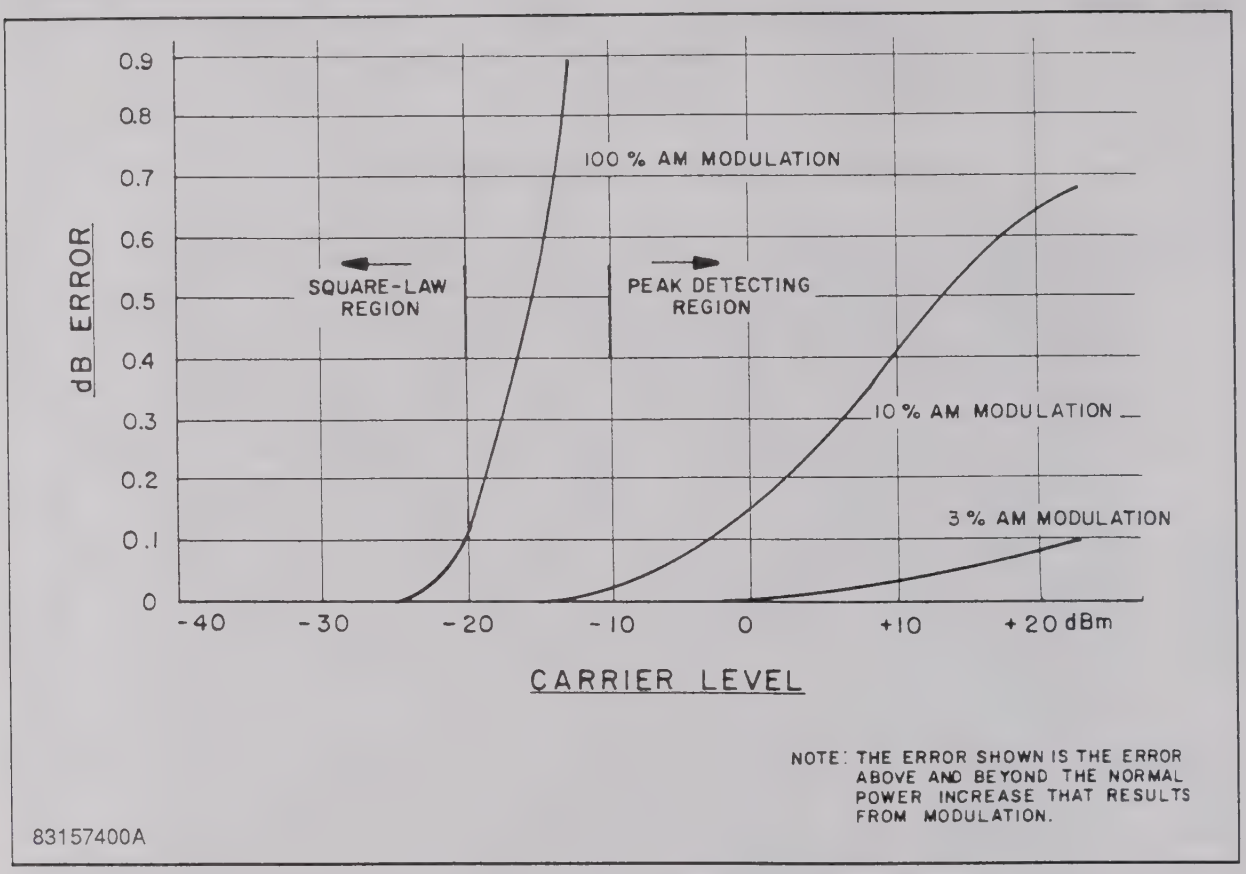

Figure 4-13. Error Due to AM Modulation (51013 Diode Sensor)

4-42. WAVEFORM SENSITIVITY.

4-43. Thermal sensors are insensitive to the waveform because they average RF power over many tens of milliseconds. Modulated signals, non-sinusoidal waveforms, and even pulses can be detected without distortion of the measurement. Thermal sensors are referred to as TRMS responding.

4-44. Diode sensors are also TRMS responding below about -20 dBm (-10 dBm and 0 dBm for attenuated models 51015 and 51033). This response characteristic is obtained because the sensors are dual diode types, and diodes respond in square-law fashion at low and medium levels. This is not an approximation, but rather an inherent effect. This effect results from the fact that the diodes do not turn on and off as switches, but behave as signal dependent resistors instead. Even with no signal input, the diodes have a finite conductance, and this conductance is modulated on a cycle by cycle basis to give a net DC offset proportional to the power.

4-45. The square-law response can be seen in Figure 4-13, where a 100% amplitude modulated signal is shown to have virtually no effect on the measured power at low levels. Of course, frequency modulated and phase modulated signals can be measured at any level, since the envelope of these modulated signals is flat. Frequency shift keyed (FSK) and quadrature modulated signals also have flat envelopes and can be measured at any power level.

4-46. At higher power levels (above approximately -10 dBm for the 51013 sensor), the diodes operate as peak detectors. The Model 4220 is software calibrated to calculate the RF power based on a shaping transfer function (RF to DC) for each sensor type. However, only measurements of RF signals with flat envelopes (CW, FM, PM, FSK, quadrature, etc.) are valid in this region and in the transition region from -20 dBm to -10 dBm.

4-47. CHART RECORDER OPERATION.

4-48. The chart recorder output is a DC voltage from 0 to 13 volts. In the power mode, the output voltage is equal to the digits displayed on the main data display divided by 1000. In the dBm or dBr modes, the output voltage is directly proportional to the level of the RF signal being measured. 0 dBm is at 8.0 volts with a sensitivity of 1.0 volt/10 dB over the range of the sensor. The output impedance is 9.09 kilohms, which gives the user the option of loading it with 1 kilohm, thereby reducing the full scale output to 1 volt. The normal 12-bit resolution is still maintained with this method. With

a 1 megohm load, the circuit is essentially open and the error is small. Absolute accuracy is ±3%

4-49. REMOTE (GPIB) OPERATION.

4-50. Introduction. If the Model 4220 is equipped with the IEEE-488 option, the instrument can be operated remotely through an IEEE-488-1978 interface. The IEEE-488 is a hardware standard which describes the communication and handshaking across the 8-bit parallel bus between a bus controller and up to 15 instruments.

4-51. The Model 4220 interfaces to the bus using a 9914A bus interface IC and tristate buffers. No DMA operations are supported. IEEE-488 capabilities are as follows:

C0	NO CONTROLLER	Capability
SH1	SOURCE HANDSHAKE	Complete capability
AH1	ACCEPTOR HANDSHAKE	Complete capability
RL1	REMOTE LOCAL	Complete capability
DC1	DEVICE CLEAR	Complete capability
DT1	DEVICE TRIGGER	Complete capability
SR1	SERVICE REQUEST	Complete capability
PP0	PARALLEL POLL	No capability
TE0	EXTENDED TALKER	No capability
T6	BASIC TALKER	Complete capability except for talker only
LE0	EXTENDED LISTENER	No capability
L4	BASIC LISTENER	Complete capability except for listener only

4-52. Local Operation. This is the front panel operation of the instrument. The instrument initializes to the local mode on bus power on, and the remote mode becomes active only when the instrument is remote addressed by the bus controller. Once in the remote mode, the instrument can be returned to the local mode in any of three ways: by a GTL (go to local) command from the bus controller, by turning off power to the instrument, or by pressing the front panel (LOCAL) key. The third method can be disabled by a local lockout (LLO) command issued by the bus controller.

4-53. Remote Operation. In the remote mode, all front panel key closures are ignored except for the (LOCAL) key (which may also be disabled by a LLO command from the bus controller). When the instrument is in the remote mode, the front panel REM annunciator is illuminated.

4-54. Bus Address. The IEEE-488 listen/talk address (MLTA) of the instrument can only be set or altered from the front panel of the instrument through use of the ADRS key. Refer to paragraph 3-16.

4-55. Terminating Characters. To inform the instrument that a message has been completed, the bus controller must end all messages with a terminating character. When addressed to listen, the 4220 requires either a carriage return or line feed character. When addressed to talk, the 4220 can send several combinations of terminating characters as required by the controller employed. Selection of terminating characters is done as part of the instrument calibration process. (Refer to table 6-4 and paragraph 6-34 k for setting EOS.)

4-56. Listen Operation. The instrument may be addressed as a listener without regard for remote or local mode. When the listener state is set by the bus controller, the instrument will receive bytes over the bus and place them in its input buffer, and the front panel LSN annunciator will be illuminated. For listen operation, the input buffer is 150 characters long. Only one message can be entered into the input buffer at a time. A second message cannot be sent until the instrument has processed the previous message.

4-57. Talk Operation. When the instrument is requested to talk, the instrument response will depend on how it has been set up. The setup is either through talk modes or talk array commands. Talk modes are associated with making measurements; talk array commands are associated with the downloading of calibration data and instrument states. Refer to paragraph 4-67 for setup of the talk mode.

4-58. Only one instrument at a time can be addressed to talk, but many instruments can be addressed to listen simultaneously. When the Model 4220 is in the talk mode, the front panel TLK annunciator is illuminated. The format for each talk message is different and is explained in the paragraphs that follow.

4-59. IEEE-488 Command Supported. The Model 4220 supports the following standard IEEE-488 commands:

a. Interface Clear Command. The interface clear (IFC) command forces all devices on the bus to clear their interfaces, and returns the instrument to local and the bus to an initialized state, clearing the error condition. This command can only be issued by the bus controller in charge. The Model 4220 responds by clearing the interface and executing the equivalent of the local command.

b. Device Clear. For this instrument, the device clear (DCL) command operates the same way as the IFC command described above.

c. Group Execute Trigger. The group execute trigger (GET) command allows the bus controller to issue a trigger to all instruments on the bus simultaneously. The Model 4220 will save the current reading at the time of the GET command and return it at the time of the next talk message mode. This is in essence a bus latch. The instrument must be set to one of its trigger modes. See paragraph 4-111.

d. SRQ. The service request (SRQ) allows an instrument to inform the bus controller that some special event has occurred. The instrument then expects the bus controller to perform a serial poll to determine what event has occurred. Events that generate service requests include instrument error, measurement error, measurement is ready, and zeroing is completed. When the instrument SRQ is active, the front panel SRQ annunciator is illuminated.

e. Serial Poll. The serial poll (SP) command on the bus allows the bus controller to check the SRQ status byte of each instrument to determine which instrument is requesting service. The byte returned by the Model 4220 is composed of multiple bits that represent different status and error conditions. These conditions are individually maskable, as shown in Table 4-7.

f. Parallel Poll. The parallel poll (PP) command is not supported.

4-60. Number Formatting. Number formatting is shown for each of the commands in the paragraphs that follow, but general rules are as follows:

a. Fixed or floating formats are accepted.

b. The optional + or - may precede the mantissa and/or the exponent.

c. An optional decimal point may appear at any position within the mantissa. A decimal point in the exponent is ignored.

d. The optional "E" for exponent may be upper or lower case.

e. All ASCII characters below and including ";" (3Bh) are considered command delimiters. The ASCII characters " " (20h), "," (2Ch), ";" (3Bh), and ":" (3Ah) are considered numeric delimiters.

4-61. String Format. String formatting is as follows:

a. The programming sequence is in natural order, that is, a function mnemonic is sent first, followed by the argument value (parameter), if applicable.

b. The data strings sent to the instrument are not case sensitive. This means lower case and upper case are the same.

c. Spurious numbers occurring in the listen string are ignored.

d. All block modes have formatted data arrays or ASCII strings. See Tables 4-3 and 4-4 for commands and paragraphs 4-82 thru 4-106 for format..

4-62. Listen Parameter Commands. Listen parameter commands are listed in Table 4-1. These are commands, received by the instrument, that expect one numerical value to follow for setting a particular operating condition. Except as noted in the table, these commands correspond to specific front panel commands. Key commands correspond to single keystrokes; non-key commands are submodes or menu types of data entry.

4-63. The numeric value (parameter) can be sent in the next listen string if the listen parameter command was the last value of the previous string. If, for any reason, a command is sent without a parameter following the command, the CL command can be used to clear the active command, or a new command can be used. The parameter number listed in Table 4-1 is the number returned when the talk parameter mode (talk mode 6) is exercised.

TABLE 4-1. LISTEN PARAMETER COMMANDS

Mnemonic	Function and Limits	Description	Parameter No.
SS #	Sensor select #1-4	Corresponds to SENSOR SELECT keystoke	1, N
FL #	Filter time select # 0.05 to 20.00 in 0.05 steps	Corresponds to FILTER keystoke	3, N (0=FA)
FR #	Frequency select # 0-110	Corresponds to FREQ keystroke (sensor dependent)	4, N
RS #	Range select # 0-6	Corresponds to RANGE keystoke	5, N (-1=RA)
SR #	Set dBr reference # -99.99 to 99.99 in 0.01 steps	Corresponds to SET keystroke	6, N
TM #	Talk mode # 0-6	Sets talk mode for IEEE-488 bus operation	8,N
SM #	SRQ mask # 0 -255	Sets SRQ mask for IEEE-488 bus operation	11, N
FD #	dB cal factor # -3.00 to 3.00 in 0.01 steps	Selects dB cal factor function	10, N

4-64. Listen Action Commands. Listen action commands are listed in Table 4-2. These commands initiate an action without any parameters being sent. The key commands correspond to single instrument keystrokes.

4-65. Listen Array Commands. Listen array commands listed in Table 4-3 transfer arrays of data (more than one parameter) to the instrument. Sensor data and DC calibration data are typical data. The data array is formatted as in paragraphs 4-87, 4-94, and 4-104. The actual amount of data depends on the specific command being used. Listen array commands are only operable over the bus, and have no application from the front panel.

4-66. The talk array commands listed in Table 4-4 build a talk string in the talk buffer for transmission. Not for general purpose measurement (the talk modes are used for that), the talk array commands are used for transmitting arrays of data (more than one parameter), such as sensor data and DC calibration data. The buffer contents are dispersed at the time of the next instrument talk request. These commands automatically change the talk mode to talk mode 7, then reset the Model 4220 to its previously selected talk mode. This is the only time that the instrument uses the talk buffer or talk array mode. Talk array commands are operable only over the bus.

4-67. Talk Modes. When the Model 4220 is requested to talk, it responds according to how it has been set up. The talk setup is either through talk array commands or talk modes. Talk modes are associated with making measurements; talk array commands are associated with downloading of calibration data and instrument states. The talk modes are described in the following paragraphs.

TABLE 4-2. LISTEN ACTION COMMANDS

Mnemonic	Function	Description	Mnemonic	Function	Description
AD	Address	Calls up instrument bus address	MS	Measure settled	Sets settled measurement mode
CF	Calibrator off	Turns off 50 MHz calibrator	PW	Watts select	Corresponds to WATTS keystroke
CL	Clear	Clears error number and error	RA	Autorange	Sets instrument to autorange
CN	Calibrator on	Turns on 50 MHz calibrator	RB	Recorder bottom	Sets recorder output to 0.0 volt
CP	Calibrate	Corresponds to CAL keystroke	RN	Recorder normal	Sets recorder output to normal operation
DB	dBm select	Corresponds to dBm keystroke	RT	Recorder top	Sets recorder output to +10.0 volts
DF	Display off	Turns off instrument display	TF	Trigger filtered	Selects filtered trigger
DN	Display on	Turns on instrument display	TN	Trigger normal	Selects normal trigger
DR	dBr select	Corresponds to dBr keystroke	TR	Bus trigger	Bus trigger command
FA	Auto filter	Sets instrument to auto filter	TS	Trigger settled	Selects settled trigger
LR	Load reference	Corresponds to LOAD REF keystroke	ZR	Instrument zero	Corresponds to ZERO keystroke
MF	Measure filtered	Sets filtered measurement mode	:D	Decrement cal numeric value	Corresponds to down keystroke
MN	Measure normal (free run)	Sets normal free run measurement mode	:E	Enter	Corresponds to ENTER keystroke
			:L	Return to local	Corresponds to (LOCAL) keystroke
			:U	Increment cal numeric value	Corresponds to up keystroke
			?ID	Talk instrument ID	Calls up instrument identification

TABLE 4-3. LISTEN ARRAY PARAMETER COMMANDS

Mnemonic	Function	Description
SI	Sensor ac calibration data in	Refer to paragraph 4-84
DI	DC calibration data in	Refer to paragraph 4-101
FI	Sensor high frequency calibration data in	Refer to paragraph 4-92

TABLE 4-4. TALK ARRAY COMMANDS

Mnemonic	Function	Description
SO	Sensor calibration data out	Refer to paragraph 4-88
DO	DC calibration data out	Refer to paragraph 4-104
FO	Sensor high frequency calibration data out	Refer to paragraph 4-96

TABLE 4-5. TALK MODES

Talk Mode	Description
0	Talk measurement floating point
1	Talk measurement with units
2	Talk error
3	Not used
4	Talk channel status
5	Talk instrument status
6	Talk parameter
7	Talk array
8	Not used

4-68. The Model 4220 supports seven talk modes of operation, as listed in Table 4-5. Once the talk mode has been set, the bus controller need only tell the Model 4220 to talk and it will respond according to the talk mode.

4-69. Talk modes 0 through 6 can be set directly by use of the talk mode (TM) command. For these modes, the instrument will remain in the selected mode until the talk mode is changed or until a talk array command is received. Talk mode 7 is a temporary talk mode that is automatically enabled in response to a talk array command. This mode cannot be set by the bus controller directly. This temporary talk mode is disabled when the talk array operation is complete.

4-70. The default condition for the talk mode is 0. The talk modes are described individually in paragraphs 4-71 through 4-80.

4-71. Talk Mode 0 (Talk Measurement Floating Point). The talk mode 0 format is as follows:

#1,#2

where:

#1 is the error flag (1 = error, data invalid).

#2 is the measurement in floating point notation in the units selected (dBm, dBr, or milliwatts). In watts mode, the unit is fixed at mW.

Examples:

0,0.00E00 - No error, power is 0.00 dBm

1,0 - Under range error at -75.00 dBm

0,98.9E-6 - No error, power is 98.9 nW

4-72. Talk Mode 1 (Talk Measurement with Units). The format for talk mode 1 is as follows:

#1,$1

where:

#1 is the error flag (1 = error).

$1 is the measurement. The format is fixed point followed immediately by a three character string that indicates the unit of measurement. Possible units are "dBm", "dBr", "nW", "uW", "mW", and "W". If needed, the string can be parsed externally into a number and a three character message.

Examples:

0,0.00dBm - No error at 0.00 dBm

1,0dBm - Under range error at -75.00 dBm

0,98.9uW - No error at 98.9 microwatts

4-73. Talk Mode 2 (Talk Error). The talk mode 2 format is as follows:

#1,#2,#3

where:

#1 is the instrument error number. A 0 will always be reported in this position.

#2 is the measurement error, from 0 to 99. A 0 indicates no error. Refer to Table 4-6 for error messages.

#3 is the channel reporting errors. A 0 will always be reported in this position.

Execution of this talk mode automatically clears the instrument error after it has been reported. If more than one error occurs, the instrument will indicate the first one that occurred.

Examples:

0,0,0 - No error is reported

0,3,0 - Power level is underrange

4-74. Talk Mode 3 (Talk Error with Message). Not used by the 4220.

4-75. Talk Mode 4 (Talk Channel Status). The format for talk mode 4 is as follows:

TABLE 4-6. ERROR MESSAGES

Error Message Code	Description
0	No Errors
1	Number entry out of range for parameter set.
2	Unused
3	-LO- indication on display. Is caused by a. Power level below amount allowed in dBm display during autorange b. Power level below amount allowed for range set in watts or dBm display.
4	-HI- indication on display. Is caused by a. Power level above amount allowed in dBm display during autorange. b. Power level above amount allowed for range set in watts or dBm display.
5	Occurs when input channel attempts to autorange below the range 0. Caused by incorrect zeroing of channel or a sensor which is damaged or not connected.
6	Unable to zero instrument because power is applied to the sensor, the sensor is damaged, or the sensor is not connected.
7 thru 23	Unused
24	Frequency out of range of entry. This error applied for sensors not calibrated at the default frequency of 0 GHz. The instrument initializes to 0 Ghz.
25 thru 38	Unused
39	Calibration attempted when power exceeds ±3 dB of the 0 dBm reference, or when calibration is attempted at ±3 dB from -10 dBm, +10 dBm or +20 dBm.
40 thru 41	Unused
42	Calibration attempted before digital filter is full. Operators must wait until the default filter or set filter time has elapsed before calibrating.
44 thru 95	Unused
96	During calibration of ADZERO, fullscale was not done.
97	Unit has memory protection jumper engaged during operation.
98	Unit has not been initialized and requires the memory protection jumper to be engaged.
99	On some 4220 options, the GPIB is not installed.

#1,#2,#3,#4,#5,#6,#7

where:

#1 is always 1 in the 4220

#2 is always 1 in the 4220

#3 is the measurement units that the channel is set;

0 Power in watts, milliwatts, microwatts, or nanowatts

1 Power in dBm

2 Power in dBr

#4 indicates the trigger mode of operation;

0 Measure Normal (also known as free-run)

1 Measure Filtered

2 Measure Settled

3 Trigger Normal

4 Trigger Filtered

5 Trigger Settled

#5 is always 0 in the 4220

#6 is always 0 in the 4220

#7 is the software version number.

4-76. Talk Mode 5 (Talk Instrument Status). The format for talk mode 5 is as follows:

#1,#2,#3,#4

where:

#1 is always 0 in the 4220

#2 indicates calibrator status;

0 off

1 on

#3 is always 0 in the 4220

#4 is always 0 in the 4220

4-77. Talk Mode 6 (Talk Parameter). The format for talk mode 6 is as follows:

#1,#2

where:

#1 is the active parameter number (0 = no parameter selected).

#2 is the active parameter value, for example "frequency". The units are defaulted.

4-78. This command returns two numbers which describe the current "opened" or selected parameter in the instrument and its value. For example, the frequency to which the instrument is set can be read over the bus. To read a parameter, it must be "opened" first as described in paragraph 4-79. A parameter in the Model 4220 is defined as a front panel or bus command that allows or requires a numerical value to be entered into it. The parameters and parameter numbers are listed in Table 4-1. The data sent over the bus is the same as the data that would appear on the instrument displays when the parameter is selected.

4-79. To use this talk mode, the instrument is first placed in talk mode 6 and a parameter is then opened (made active) by pressing the appropriate key or by sending the bus command. No numeric value should follow and the clear command should not be used. Then, while the parameter is active, a talk command is issued to the instrument and the data for that parameter is sent out on the bus. A parameter can be deactivated by simply entering a number or sending another command.

Examples:

0,0 - No parameter is active and the second value should be ignored

10,-3.00 - The dB cal factor is currently set to -3.00 dB.

5,1 - Range 1 is set.

4,1.23 - The frequency is set to 1.23 GHz

4-80. Talk Mode 7 (Talk Array). Each of the different talk array commands has a different format. (Refer to the applicable section of paragraph 4-69.) This talk mode is not directly settable by the bus controller; it is set internally automatically by execution of one of the talk array commands. Talk mode 7 builds a data string in the talk buffer for a one time transmission. It is used to send an array of numerical data or a string of character data, such as sensor and/or calibration data. Once executed, this mode is automatically cleared to its previously selected value or default condition.

4-81. IEEE-488 BUS ONLY COMMANDS.

4-82. General. The following paragraphs cover commands that are available only under remote control on the bus.

4-83. Talk Mode (TM) Command. The talk mode command is used to change to a selected talk mode. The range of data for this command is from 0 to 6. Talk mode 7 can only be set indirectly by execution of a talk array command. The talk mode command is classified as a listen parameter command.

Example:

TM1 - Set talk mode 1 which is talk measurement with units.

4-84. SI Command. Used in conjunction with the SO command, this command is used to send a portion of the sensor calibration data to the Model 4220 in the form of an

array of numeric data. In this way, sensor data can be transferred from one instrument to another, or stored on a disk.

4-85. The data is the sensor model, sensor S/N, and the 14 point linearity data (AC calibration data) for a selected sensor. This command complements the SO command over the bus, and the SO command would normally be the source of the data string for this command. The SI command is classified as a listen array command.

4-86. In addition to the 14 point linearity data, each sensor has high frequency calibration data, which is loaded with the FI command. (See paragraph 4-92.)

4-87. The format for the SI command is as follows:

SI sensor model, sensor serial number,
U0,U1,U2,U3,U4,U5,U6,D0,D1,D2,D3,D4,D5,D6

where:

Sensor model is a number in the form 51XXX, whereXXX is a three digit number sent to the instrument. Sensors must be resident in the instrument firmware.

Sensor serial number is from 0 to 9999, representing the last 4 digits of the sensor's full serial number.

U0 through U6 are the upscale gain factors (1000 to 9999, nominally 5000).

D0 through D6 are the downscale factors (-999 to +999).

Each numeric value must be separated by a valid delimiter.

Example:

SI13,1234,5012,5003,5032,5013,4995,5005,4891,
-20,-21,2,-3,-14,15,6

4-88. SO Command. Used in conjunction with the SI command, this command is used to send sensor 14 point linearity data out to the bus controller. (Refer to the SI command description for the general use of these commands.) Sensor data also includes high frequency calibration data, but this data is handled with the FI command. See paragraph 4-92.

4-89. When executed, the SO command instructs the instrument to build an array of numeric data in the talk buffer for transmission by the next talk request. The array consists of sensor model, sensor S/N, and numeric data representing the 14 point linearity data (AC calibration data) for a selected sensor. This command complements the SI command over the bus, and the SI command would normally be the destination of the data string of this command. The SO command is classified as a talk array command.

4-90. The talk mode is set temporarily to talk mode 7 (talk array) when this command is executed. After execution, the talk mode is reset. A clear command will also reset the talk mode.

4-91. Formats are as follows:

a. To the instrument in a listen string: SO

b. From the instrument in the next talk string: sensor model, sensor serial number, U1,U2,U3,U4,U5,U6,D0,D1,D2,D3,D4,D5,D6, where the format descriptions are the same as in paragraph 4-87. Each numeric value must be separated by a valid delimiter.

Example:

To the instrument in a listen string: SO

From the instrument in the next talk string:
13,1234,5023,5001,5012,5010,4997,5005,5003,10,
13,-2,-23,14,-15,6

4-92. FI Command. Used in conjunction with the FO command, this command is used to send sensor high frequency calibration data to the Model 4220 for a selected sensor in the form of an array. In this way, sensor data can be transferred from one instrument to another, or stored on a disk. In addition to the high frequency calibration data, there is 14 point calibration data for the sensor, but this is handled by the SI command.

4-93. The data is for a selected sensor. This command complements the FO command over the bus, and the FO command would normally be the source of the data string for this command. This command is classified as a listen array command. Data is loaded in blocks from 1 to 12 pairs.

4-94. The command format is as follows:

FI n, FRn, CRn, FRn+1, CFn+1, ... FRN+11, CFn+11

where:

n is the table number pointer, from 0 to 35.

FRn is the first frequency of this group, from 0.00 to 110 GHz in 0.01 GHz increments. It is sensor dependent.

CFn is the first dB cal factor for this group, from -3.00 to +3.00 dB in 0.01 dB increments.

Each numeric value must be separated by a valid delimiter.

4-95. The total number of frequency points is limited to 36 for sensors 1 through 4. The table number pointer is the beginning location for the frequency/dB cal factor pairs. The pointer must not exceed 24 if the group contains 12 points, for a total of 36 points. Frequency cal points must be in numerical order of frequency. Generally, the first point is at 0 GHz, with a cal factor of 0., so

Example:

FI0,0.00,0.00,1.00,-0.05,2.00,-0.07,3.00,0.10,4.00,
-0.06,5.00,-0.05,6.00,0.00,7.00,0.13,8.00,0.42,
9.00,0.34,10.00,0.00,11.00,0.15,

FI12,12,.12,13,-.13,14,1.14,15,.85

4-96. FO Command. Used in conjunction with the FI command, this command is used to send sensor high frequency calibration data out to the controller. Refer to the FI command description for the general use of these commands. Data points are loaded in blocks of 12.

4-97. When executed, this command instructs the instrument to build an array of numeric data in the talk buffer for transmission by the next talk request. The array consists of numeric data representing the dB cal factor information for a selected sensor. The FO command is classified as a talk array command.

4-98. The talk mode is temporarily set to talk mode 7 (talk array) when this command is executed. After the command has been executed, the talk mode is reset to talk mode 0 (talk measurement). A clear command will also reset the talk mode.

4-99. The format for the FO command is as follows:

a. To the instrument in the listen string: FO n

b. From the instrument in the next talk string: FRn, CRn, FRn+1, CRN+1, ... FRn+11, CFn+11

where:

n is the table number pointer, from 0 to 35.

FRn is the first frequency of this group, from 0.00 to 110 GHz in 0.01 GHz increments. It is sensor dependent.

CRn is the first dB cal factor for this group, from -3.00 to +3.00 dB in 0.01 dB increments.

Each numeric value will be separated by a comma.

4-100. Refer to the FI command for limitations on the pointer and starting frequencies, and for general use of this command.

Example:

Command sent to the instrument: FO 0

Numeric array built into the talk buffer:
0.00,0.00,1.00,-0.05,2.00,-0.07,3.00,-0.10,4.00,
-0.06,5.00,-0.05,6.00,0.00,7.00,0.13,8.00,0.42,
9.00,0.34,10.00,0.00,11.00,0.15

Command sent to the instrument: FO 3

Numeric array built into talk buffer:
3,00,-0.10,4.00,-0.06,5.00,-0.05,6.00,0.00,7.00,
0.13,8.00,0.42,9.00,0.34,10.00,0.00,11.00,0.15,
12.00,0.32,13.00,0.25,14.00,0.43

4-101. DI Command. Used in conjunction with the DO command, this command is used to send DC calibration data to the instrument. In this way, calibration can be done in an automatic test station. Calibration data can also be retrieved from an already calibrated unit and stored on a disk.

4-102. The data is a gain constant for each range and an ADZERO term which is a downscale adjustment. All are stored in nonvolatile RAM.

4-103. The DI command complements the DO command. It is classified as a listen array command. The format is as follows:

DI G0,G1,G2,G3,G4,G5,G6,ADZERO

where:

G0 through G6 are the gain constants for ranges 0 through 6, ranging from 4000 to 7500 (nominally 5000)

ADZERO is the A/D converter downscale adjustment, ranging from -10 to +10, nominally 0.

Each numeric value must be separated by a valid delimiter.

Example:

DI 5000,5001,5002,5003,5004,5005,5006,-1

4-104. DO Command. Used in conjunction with the DI command, this command is used to load DC calibration data out to a controller for later re-entry into the instrument. When executed, this command instructs the instrument to build an array of numeric data in the talk buffer for transmission by the next talk request. The array consists of a gain constant for each range, and an ADZERO term which is a downscale adjustment. They are stored in nonvolatile RAM, and is classified as a talk array command.

4-105. The talk mode is temporarily set to talk mode 7 (talk array) when this command is executed. After the talk command has been executed, the talk mode is reset to talk mode 0 (talk measurement). A clear command will also reset the talk mode.

4-106. The formats for the DO command are as follows:

a. To the instrument as a listen string: DO

b. From the instrument in the next talk string: G0,G1,G2,G3,G4,G5, G6, ADZERO

where:

G0 through G6 are the gain constants for ranges 0 through 6, from 4000 to 7500 (nominally 5000, except range 6, which is 6635)

ADZERO is the A/D converter downscale adjustment, from -10 to +10 (nominally 0)

Each numeric value must be separated by a valid delimiter.

TABLE 4-7. SRQ MASKS

Bit	Description
0	Set bit indicates that an instrument error has occurred
1	Set bit indicates that a measurement error has occurred
2	Set bit indicates that a measurement is ready
3	Set bit indicates that a zeroing command is complete
4	Not used; should be reset (0)
5	Not used; should be reset (0)
6	Set bit indicates that an SRQ is active; this is a summary bit used in serial poll, not a masked bit
7	Not used; should be reset (0)

Example:

To the instrument in a listen string: DO

From the instrument in the next talk string:
5000,4889,5002,5029,5034,4990,6645,-1

4-107. DF Command. This command is classified as a listen action command. Its functions are to blank the front panel display for secure ATE applications and to speed up operations by reducing the number of tasks that have to be performed by the Model 4220. When the display is turned off, the display hardware is still functional, but it is not updated for certain types of information. The data that is still displayed is the instrument IEEE-488 bus status. This data is displayed on the REM, TLK, LSN, and SRQ annunciators.

4-108. DN Command. This command enables the front panel display, complementing the DF command. This command is classified as a listen action command.

4-109. SM (SRQ Mask) Command. This command is used to set the SRQ mask which selectively enables service requests generated by the Model 4220. This command is classified as a listen parameter command. The range of numeric entry is from 0 to 255. The SRQ mask is logically ANDed with the SRQ sources to determine if an SRQ should be generated. The SRQ bit map is shown in Table 4-7. For more information on SRQ and the related serial poll, refer to paragraph 4-59.

Examples:

SM 0 - Disable all service requests

SM 2 - Enable SRQ only on measurement errors

SM 8 - Enable service request only when a zeroing operation is complete

4-110. MEASURED AND TRIGGERED OPERATION AND SETTLED READING.

4-111. General. Three measurement modes and three triggered modes are available over the bus. They are:

a. Measure Normal (also known as free-run)

b. Measure Filtered

c. Measure Settled

d. Trigger Normal

e. Trigger Filtered

f. Trigger Settled

The instrument must be in remote bus operation to invoke these modes of operation. When in local operation, only measure normal is available. The three measurement modes are each self triggering (free running) while the triggered modes require a bus trigger command. The operation of each mode is modified by filter selection and range selection. See paragraphs 4-16 and 4-18. The modes are described below.

4-112. Measure Normal (MN). This is the mode to which the instrument initializes at power up when the local command is issued in bus operation or when returning from a calibration mode.

4-113. Measure Filtered (MF). In this mode, the front panel display is self triggered and continuously updated. In response to a step change in power of approximately 0.02 dB or an internal range change, the front panel displays the "---- ----" (dashes) message until the digital filter time constant has elapsed. This mode guarantees that the reading is filtered by holding off the display of partially filtered readings.

4-114. Measure Settled (MS). In the MS mode, the front panel display is self triggered and continuously updated. In response to a step change in power of approximately 0.02 dB or an internal range change, the front panel displays the "---- ----" (dashes) message until the digital filter and settled filter time constants have elapsed. Thus, the effective filter time is twice the default or set filter time constant. This mode guarantees that the reading is filter-settled by holding off the display of partially filtered and unsettled readings.

4-115. Trigger Normal (TN). In this mode, the front panel displays the "trig trig" message until the 4220 is triggered

by a bus command. The instrument continuously measures power as in the measure normal mode but does not display the reading. When triggered, the instrument captures the most recent measurement and displays the reading until another trigger command changes the display. This mode provides a quick response to trigger and the capability to hold a reading until required. However, the user is required to assure stability of the reading at the time of trigger.

4-116. Trigger Filtered (TF). The 4220 displays the most recent measurement until it receives a bus trigger command. The instrument then discards all previous measurements and begins the measure filtered mode. It displays the "trig trig" message until the digital filter time constant has elapsed. The instrument displays and holds the reading until another bus trigger command is received. In this mode, the digital filter guarantees a filtered reading upon trigger and the capability to hold a reading until required.

4-117. Trigger Settled (TS). The 4220 displays the most recent measurement until it receives a bus trigger command. The instrument then discards all previous measurements and begins the measure settled mode. It displays the "trig trig" message until the digital filter and settled filter time constants have elapsed. Thus, the effective filter time is twice the default or set filter time constant. The display then holds the reading until another bus trigger command is received. This mode guarantees a filtered-settled reading upon trigger and the capability to hold a reading until required.

4-118. IEEE PROGRAMMING EXAMPLES.

4-119. The following programming examples demonstrate, bus operation of the 4220. The examples are written in a general format of BASIC and are not an example of any specific implementation of the language. The examples assume that the 4220 is the only instrument connected to the bus so that all commands address the 4220.

4-120. In the examples, "INPUT" refers to the case where the instrument is addressed as the talker; "OUTPUT" indicates that the controller is the talker.

4-121. Example 1. Zero the instrument and take a reading from a signal generator.

Setup conditions	:	Select sensor #3
		Frequency of 5 Gigahertz
		Reading in milliwatts and also dBm
		Filter of 3 seconds
		Generator output is -17 dBm
OUTPUT "SS3"	:	use sensor #3
OUTPUT "FR5"	:	set frequency to 5 GHz
OUTPUT "FL3"	:	set filter to 3 seconds
OUTPUT "TM0":		set TALK MODE to "0"

disconnect sensor from generator

WAIT 1000	:	wait one second
OUTPUT "ZR"	:	zero instrument
WAIT 5000	:	wait for zero to complete

reconnect sensor to generator

WAIT 3000	:	the filter time constant
INPUT A,B	:	get reading from 4220
PRINT A	:	print "0" which is the error code
PRINT B	:	print ".01995" which is the power in milliwatts

change talk mode and take another reading in dBm

OUTPUT "TM1":		set TALK MODE to "1"
OUTPUT "DB"	:	set 4220 to dBm display
WAIT 3000	:	the filter time constant
INPUT A$	:	get a reading from the 4220
PRINT A$	:	print string variable "0,-17.00dBm"

4-122. Example 2. Take triggered readings from a signal generator.

Setup conditions	:	Select sensor #2
		Power of 100 microwatts
		Frequency of 18 Gigahertz
		Reading in milliwatts
		Autofilter
OUTPUT "SS2"	:	use sensor #2
OUTPUT "FR18":		set frequency to 18 GHz
OUTPUT "PW"	:	set WATTS display
OUTPUT "FA"	:	set filter to Autofilter
OUTPUT "TM0":		set TALK MODE to "0"
OUTPUT "TS"	:	set Trigger-Settled operation

connect sensor to generator

TRIGGER	:	send bus Group Execute Trigger
INPUT C$	:	get reading from 4220
PRINT C$	:	print "0,100.00E-3" talk mode 0

change to dBm display

OUTPUT "DB"	:	set dBm operation
OUTPUT "TR"	:	send 4220 trigger command
INPUT C$	:	get reading from 4220
PRINT C$	:	print "0, -10.00E0" talk mode 0

change to TALK MODE 1

OUTPUT "TM1": set Talk Mode 1

TRIGGER : send bus Group Execute Trigger

INPUT C$: get reading from 4220

PRINT C$: print "0,-10.00dBm" talk mode 1

4-123. ERROR MESSAGES.

4-124. The error messages returned over the bus are described in Table 4-6. They are in numerical order as would be sent out over the IEEE-488 bus.

MP MASTER
MA26478